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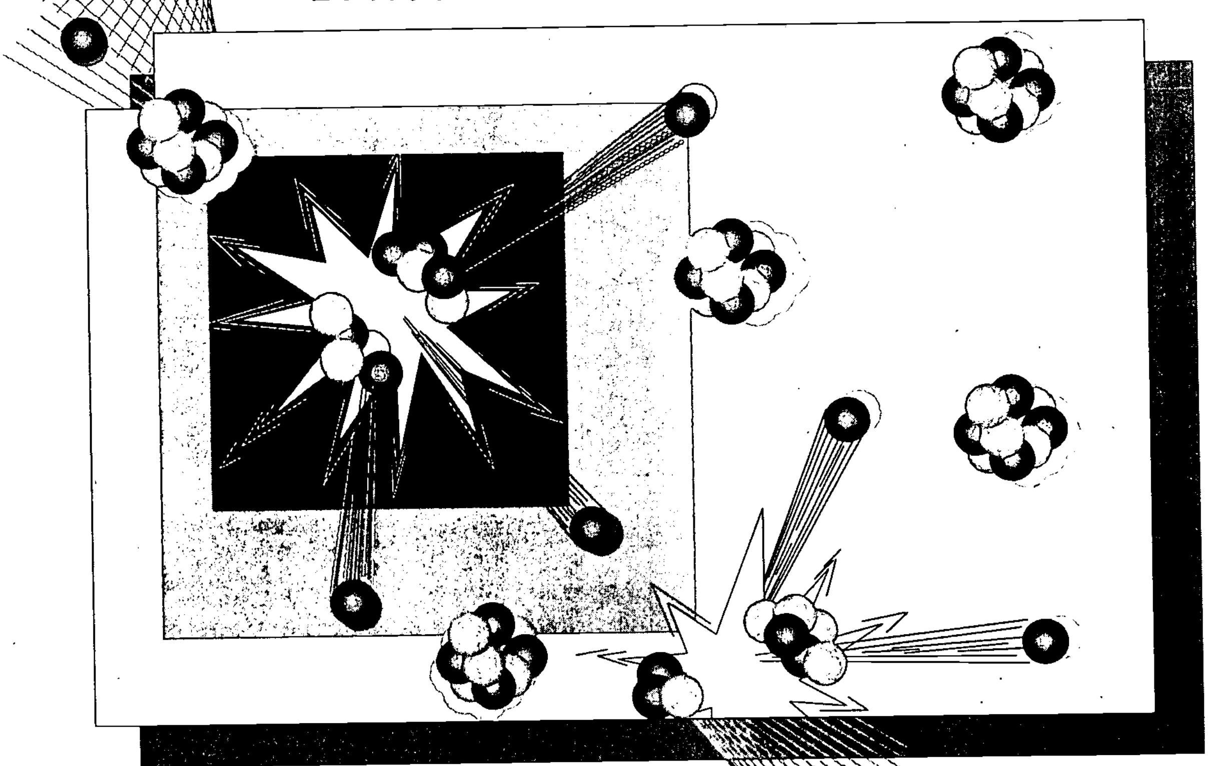
ABSTRACT

This guide is Unit 1 of the four-part series Science, Society, and America's Nuclear Waste produced by the U.S. Department of Energy's Office of Civilian Radioactive Waste Management. The goal of this unit is to help students establish the relevance of the topic of nuclear waste to their everyday lives and activities. Particular attention is focused on the sources, characteristics, and locations of spent fuel and high-level nuclear waste in the United States. The first section of Unit 1 includes two lesson plans about the nature of nuclear waste, background notes, and many charts and graphs. The second section provides further background information and provides three lesson plans that explore nuclear waste management. Activity sheets for students and transparencies for the lesson plans and background notes are included in the third section, followed by the pretest, posttest and unit test. Answers keys and a glossary are also included. Contains 24 references. (DDR)

DOE/RW-0361 TG, Rev. 1

Science, Society, and America's Nuclear Waste



Nuclear Waste

Unit 1 Second Edition
Teacher Guide

"Science, Society and America's Nuclear Waste" is a four-unit secondary curriculum. It is intended to provide information about scientific and societal issues related to the management of spent nuclear fuel from generation of electricity at nuclear powerplants and high-level radioactive waste from U.S. national defense activities. The curriculum, supporting classroom activities, and teaching materials present a brief discussion of energy and electricity generation, including that produced at nuclear powerplants; information on sources, amounts, location, and characteristics of spent nuclear fuel and high-level radioactive waste; sources, types, and effects of radiation; U.S. policy for managing and disposing of spent nuclear fuel and high-level radioactive waste and what other countries are doing; and the components of the nuclear waste management system. The four units are:

Unit 1 - Nuclear Waste

Unit 2 - Ionizing Radiation

Unit 3 - The Nuclear Waste Policy Act

Unit 4 - The Waste Management System

In the study of nuclear waste management, or any other scientific and social subject, individuals are encouraged to seek differing perspectives and points of view.

This resource curriculum was produced by the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) and has been reviewed by selected staff, faculty, and/or workshop participants from: Louisiana State University; the University of Nevada, Reno and Las Vegas; the University of Tennessee; Pennsylvania State University; Hope College in Michigan; the University of South Florida School of Medicine; the New York State Department of Education, Science, Technology, and Society Education Project; the Nevada Science Project; the National Council for the Social Studies, Science and Society Committee; and the First International Workshop on Education in the Field of Radioactive Waste Management — At the Crossroads of Science, Society, and the Environment — co-sponsored by the multinational Organization for Economic Cooperation and Development/ Nuclear Energy Agency, U.S. Department of Energy's OCRWM, and the Swiss National Cooperative for the Storage of Radioactive Waste (NAGRA). The international workshop was attended by educators and information specialists from Austria, Belgium, Canada, Finland, France, Germany, Japan, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, and the United States. This curriculum was field tested through team-teaching by science and social studies teachers in Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas.

For further information about this curriculum, please call 1-800-225-6972 (within Washington, DC, 202-488-6720) or write to:

OCRWM National Information Center
Attention: Curriculum Department
600 Maryland Ave., SW
Suite 760
Washington, DC 20024

The 1977 DOE Reorganization Act authorizes education and training activities necessary to ensure that the Nation has an adequate technical work force in energy-related research and production fields. These fields include mathematics, physics, geology, chemistry, zoology, biology, and other areas of basic and applied research. The DOE Science Enhancement Act (part of the 1991 National Defense Authorization Act) expands the Department's authorization to support science education and amends the 1977 legislation to make support for science education a major mission of the Department. Traditionally, the DOE educational emphasis has been on university-level education, with the agency providing graduate student fellowships and research appointments at DOE facilities. More recently, the education mission was expanded to include precollege education and science literacy.

DOE has been working diligently to make its contribution toward achieving our National Education Goals since their development following the 1989 Education Summit in Charlottesville, Virginia. Although DOE's work indirectly supports all the goals, DOE is especially involved in Goal # 4: "By the year 2000, U.S. students will be first in the world in science and mathematics achievement."

DOE sponsors a number of national and local energy education programs, in addition to this curriculum, through its national laboratories, energy technology centers, and various DOE program elements. For further information about these programs, please write to: U.S. Department of Energy, Office of Science Education and Technical Information, Washington, DC 20585.

Science, Society, and America's Nuclear Waste

Nuclear Waste

Unit 1 Second Edition
Teacher Guide

July 1995

Department of Energy
Washington, DC 20585

To the Teacher:

This Second Edition of the Teacher Guide accompanies the resource curriculum *Science, Society, and America's Nuclear Waste*. The curriculum, produced by the United States Department of Energy's (DOE's) Office of Civilian Radioactive Waste Management (OCRWM), is designed to assist science and social studies teachers in presenting issues related to the safe management and disposal of America's nuclear waste. The curriculum was developed, reviewed, and tested by teachers for use in grades 8 through 12.

The *Science, Society, and America's Nuclear Waste* curriculum provides information and background on energy and waste-management issues. It is suitable for use in technology and environmental science classes and in social studies classes in middle, high school, and advanced lower grades. Its content and focus are consistent with national goals to strengthen and update math and science curriculum and broaden public science literacy.

Since the curriculum was first made available to the public in 1992, and as of August 1995, more than 20,000 Teacher Guides and approximately 200,000 Student Readers have been requested by and distributed to educators of diverse disciplines in all 50 States and in 48 foreign countries.

Ancillary materials, such as videotapes, a computer diskette, and other materials referenced in the document, may be obtained by calling the OCRWM National Information Center at 1-800-225-6972 (in Washington, D.C., 202-488-6720).

Sincerely,

E. Y. Deshields

Evangeline Deshields, Manager
Office of Civilian Radioactive Waste Management
National Information Center

Notice To Educators

These **Second Edition Teacher Guides** contain statistical updates that are current as of October 1, 1994. **First Edition Student Readers** are available upon request. Since very few statistical changes were required in the Student Readers, **Second Edition Student Readers** were <u>not</u> printed. Minor differences between the two editions are underlined in your Student Reader material contained in these Teacher Guides.

References to a Monitored Retrievable Storage (MRS) Facility and the Office of the Nuclear Waste Negotiator

You will note that throughout units 3 and 4 of the curriculum references are made to the concept of a Monitored Retrievable Storage (MRS) facility. The Nuclear Waste Policy Amendments Act of 1987 (the Act) authorized the siting, construction, and operation of such a storage facility as an integral part of the Federal waste management system. The Act gave the Secretary of Energy the authority to survey and evaluate sites for a storage facility then designate one. The Act also created the Office of the Nuclear Waste Negotiator to seek a State or Indian Tribe willing to volunteer a technically suitable site, under reasonable terms to be approved by Congress.

To counter a concern that interim central storage on the surface might become permanent, Congress linked the selection of a storage site to the recommendation of a repository site to the President by the Secretary. Under this limitation, construction of a storage site cannot begin until the Nuclear Regulatory Commission issues a license for construction of a repository. In 1989, the Department of Energy announced a delay in the recommendation of a repository site until 2001, and a delay in the expected date of repository operations until the year 2010. The Secretary also told Congress that if the linkage between the MRS facility and the repository were modified, then waste acceptance at the facility could begin by 1998. This was based on the assumption that a site would be available by then. However, the linkage remains in place, the Nuclear Waste Negotiator has not been able to find a volunteer candidate site, and accumulated political experience suggests that a volunteer site for interim storage is not likely. In the absence of interim central storage, waste acceptance and offsite transport could not occur until the start of repository operations in 2010.

The Fiscal Year 1995 budget does not provide funding to OCRWM for activities related to interim storage, and the statutory authority for the Office of the Nuclear Waste Negotiator expired in January 1995. However, references to an MRS facility are still included in the Second Revision, as the concept is still included in the Nuclear Waste Policy Act, as mentioned.

Because of the changes mentioned above, this edition's lesson in Unit 4, formally titled *The Role of the Monitored Retrievable Storage Facility*, has been replaced with the lesson *The Role of the Multi-Purpose Canister*. However, most of the other references to an MRS facility found throughout the curriculum have remained intact, most notably in Unit 3. Please take special note of this new information as you plan lessons around the concept of an MRS facility.

Please note that referenced videotapes and support materials can be obtained free of charge through the **OCRWM National Information Center at 1-800-225-6972 (in Washington, DC, 202-488-6720).**

NUCLEAR WASTE

Text/Activities

Enrichment

UNIT I: Nuclear Waste/Sources, Characteristics, and Locations

Lesson	Focus	Activities/Materials Provided	Content Area/ Grade Level
What Does Nuclear Waste Have To Do with Me? (Core = 1 class period)	Helps students establish the relevance of the topic of nuclear waste to their lives.	Transparencies (4) Reading Lesson (Optional) Activity Sheet Enrichments (2) • Community Involvement • Graphing	Science & Social Studies (Grades 8-12)
Nuclear Waste: What Is It? Where Is It? (Core = 2 class periods)	Helps students establish that a national challenge exists because there is an accumulation of nuclear waste. Aids students in differentiating among types of waste and assures them that each type of nuclear waste is disposed of in a way that will provide protection of the public and environment.	Transparency Reading Lesson Reading Review Map Activity Activity Sheet Enrichments (2) • Map Activities	Science & Social Studies (Grades 8-12)

9 10

NUCLEAR WASTE
Sources, Characteristics, and Locations

Unit Purpose:

This unit helps students establish the relevance of the topic of nuclear waste to their everyday lives and activities. Additionally, the unit provides a detailed examination of the different types of nuclear waste, the geographic distribution of spent fuel and high-level nuclear waste in the United States, and it includes brief, optional review activities on energy and electricity and the nuclear fission process. Particular attention is focused on the sources, characteristics, and locations of spent fuel and high-level nuclear waste, whose management is the concern of the Nuclear Waste Policy Act. The paradoxical relationship between the total volumes and radioactivities of nuclear waste is explored. The fact that various States are projected to increase their spent fuel storage as much as 300% by the year 2000 will further highlight the urgency of this pressing national issue for students.

Unit Concepts:

A national challenge exists because there is an accumulation of nuclear waste.

1. Energy in the form of electricity is essential to our standard of living.
2. Every energy source used to generate electricity has both benefits and problems.
3. The topic of nuclear waste is important to all of us.
4. Nuclear wastes have the characteristic of being radioactive, and, therefore, they require special handling, storage, and disposal.
5. A national challenge exists because there is an accumulation of radioactive wastes and a safe and environmentally acceptable method of permanent disposal is needed.
6. There are four major classifications of nuclear waste: high-level waste, low-level waste, transuranic waste, and mill tailings.
7. Classification of nuclear waste depends on its source and the types and levels of radiation it emits.
8. Each type of nuclear waste is disposed of in a way that will protect the public and environment from hazards associated with radiation.
9. High-level waste in the form of commercial spent fuel is currently stored in 35 States.

Duration of Unit:

Three 50-minute class periods

Unit Objectives:

As a result of participation in this unit of study, the learner will be able to:

1. identify everyday uses of electricity and trade-offs of various energy sources used to generate electricity;
2. discuss the relevance of nuclear waste to his/her life;

3. list and define the four categories of nuclear waste;
4. state how each type of waste is or will be disposed of;
5. write a brief statement explaining the paradoxical relationship between the total volumes and radioactivities of nuclear wastes;
6. complete an outline map of the United States showing where spent fuel and/or high-level nuclear waste is stored and/or will be stored by the year 2000; and
7. discuss where spent fuel and/or high-level nuclear waste is currently stored in the United States.

Unit Skills:

Analyzing, comparing, critical thinking, data transferring, defining, describing, discussing, drawing conclusions, evaluating, explaining, grouping, interpreting (charts, maps, and tables), labeling, listing, mapping, reading, sorting, synthesizing, writing

Unit Vocabulary:

Byproduct, ceramic pellets, commercial, compact, controversial, cubic meter, defense high-level waste, energy source, fission, fission products, fossil fuel, fuel assembly, fuel rods, geographic, high-level waste, low-level waste, mapping, mill tailings, neutron, nuclear chain reaction, nuclear energy, nuclear powerplant, nuclear reactor, nuclear waste, pie chart, radioactive, radioactive waste, radioactivity, repository, spent fuel, transuranic, volume, waste management

Unit Materials:

Reading lessons

Energy and Electricity Review (optional), p. SR-1
Nuclear Waste: What Is It? Where Is It?, p. SR-9

Activity sheets

Electricity from Nuclear Energy, p. 107
Radioactive Wastes: Volumes and Radioactivities, p. 109
Nuclear Waste: What Is It? Where Is It?, p. 111
Geographic Distribution of Commercial Spent Fuel and Commercial and Defense High-Level Nuclear Waste, p. 115
(blank U.S. map and question/answer sheet)
Geographic Distribution of Commercial Spent Fuel and Commercial and Defense High-Level Nuclear Waste, p. 117

Background Notes:

Enrichment:

INTRODUCTION

If you are reading this Introduction, you belong to the generation that will manage high-level nuclear waste, that is, spent fuel and reprocessed waste resulting from operation of commercial nuclear generating plants. The modern world relies heavily on energy and especially electricity to maintain its lifestyle. In our Nation more than 20% of our electricity currently comes from nuclear powerplants, a contribution which is second only to coal. Therefore, it is crucial that today's students understand what this waste is, where it comes from, and how it can be disposed of safely. While an older generation is now planning for disposal of high-level nuclear waste, people your age will be our Nation's voters and workers when the plans being made now become reality. You will need to be able to make informed decisions about nuclear waste issues.

Scientific Truth

In making these decisions, it will be important to have an understanding of scientific truth and scientific inquiry. Scientific inquiry presumes that natural events occur in such consistent ways that careful and systematic study can reveal their cause and results.

Just as a detective examines clues at the scene of a crime in the hope of identifying the criminal, a scientist examines the results of a natural process to better understand the process. In this way, scientists seek to produce true knowledge. But they are the first to point out that what science achieves is not to be considered true **absolutely** or beyond change.

The history of science demonstrates this. For example, people living in Europe once thought the world was flat. Christopher Columbus dispelled that theory during his voyage of discovery. Not that long ago, scientists thought the atom could not be split. We now know that it can be.

What is considered to be true at one time may later be found to be only partially true—or in some cases, untrue. New data may also provide more evidence that supports or reinforces current understanding.

At any given time, decisions that rely on scientific data must be based on the best understanding of the meaning of the data at that time. We may say, then, that **scientific truth is true insofar as we are capable of knowing it at the time and under the circumstances surrounding the scientific inquiry**.

Individual fields of scientific research seem to go through cycles of activity. Major discoveries or advances are usually separated by periods when the results are discussed, added to, and shaped into a new and improved understanding. The new understanding includes much of the previous understanding, but often major parts of the previous understanding must be discarded.

Honest disagreements as to the correct interpretation of new data are common among scientists. This is especially true in the early stages of information gathering. To achieve scientific understanding, it is necessary that free and open discussions take place and that opposing views are fairly evaluated.

Geologic Disposal of Nuclear Waste

Nuclear waste is an unavoidable byproduct of our Nation's many research, medical, defense, and energy-producing activities that involve the use of radioactive materials.

After years of study, scientists throughout the world agree that geologic disposal is the most desirable, safest, and most acceptable way of permanently disposing of high-level radioactive waste.

The U.S. is seeking to establish a national geologic repository. Similar geologic waste disposal programs are also underway in Belgium, Canada, Finland, France, Germany, Japan, the Netherlands, Spain, Sweden, Switzerland, and the United Kingdom. Since 1992, programs have also been considered in Argentina, India, and Italy.

WHAT DOES NUCLEAR WASTE HAVE TO DO WITH ME?

Purpose:

This lesson helps students establish the relevance of the topic of nuclear waste to their everyday lives and activities.

Concepts:

1. Energy in the form of electricity is essential to our standard of living.
2. Every energy source used to generate electricity has both benefits and problems.
3. The topic of nuclear waste is important to all of us.
4. Nuclear waste has the characteristic of being radioactive, and, therefore, requires special handling, storage, and disposal.
5. A national problem has been created by the accumulation of radioactive wastes and a safe and environmentally acceptable method of permanent disposal is needed.
6. Development of a high-level waste management program involves complex societal and technical challenges.

Duration of Lesson:

One 50-minute class period

(Allow an additional class period if optional energy review is used.)

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. identify everyday uses of electricity and tradeoffs of various energy sources used to generate electricity; and
2. discuss the relevance of nuclear waste to his/her life.

Skills:

Analyzing, comparing, discussing

Vocabulary:

Byproduct, controversial, energy source, fossil fuel, nuclear energy, nuclear powerplant, nuclear waste, radioactive waste, repository, waste management

Materials:

Discussion Questions

Reading Lesson

Energy and Electricity Review (optional), p. SR-1

Activity Sheet

Electricity from Nuclear Energy, p. 107

Transparencies

Locations of Nuclear Powerplants, p. 73

What Percentage of the Electricity Generated in Your Region in 1994 Came from Nuclear Energy?, p. 75

Percentage of Electricity Generated by Nuclear Powerplants in 1994, p. 77

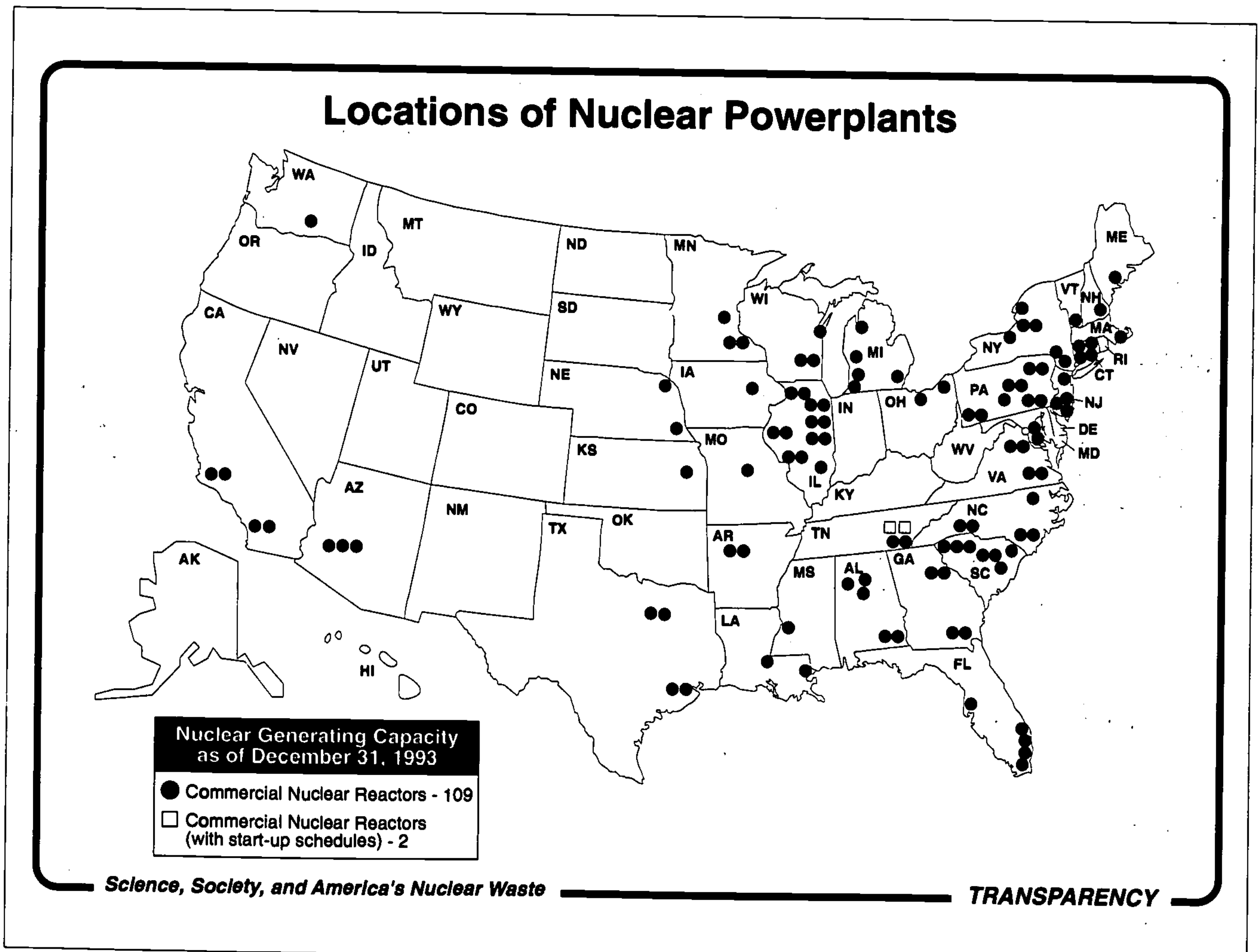
Energy Equivalents, p. 79

Share of Electrical Generation by Source, p. 81

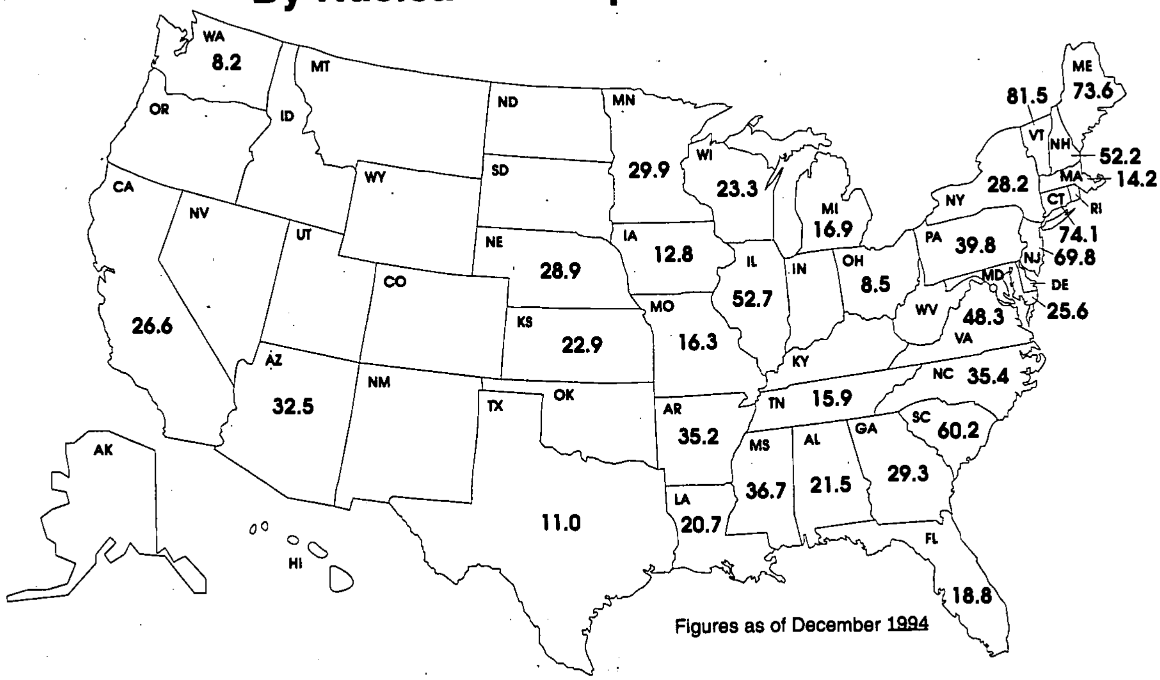
Background Notes

Updating Electricity Generation Statistics, p. 7

Generation of Electricity, p. 9



Percentage of Electricity Generated By Nuclear Powerplants in 1994



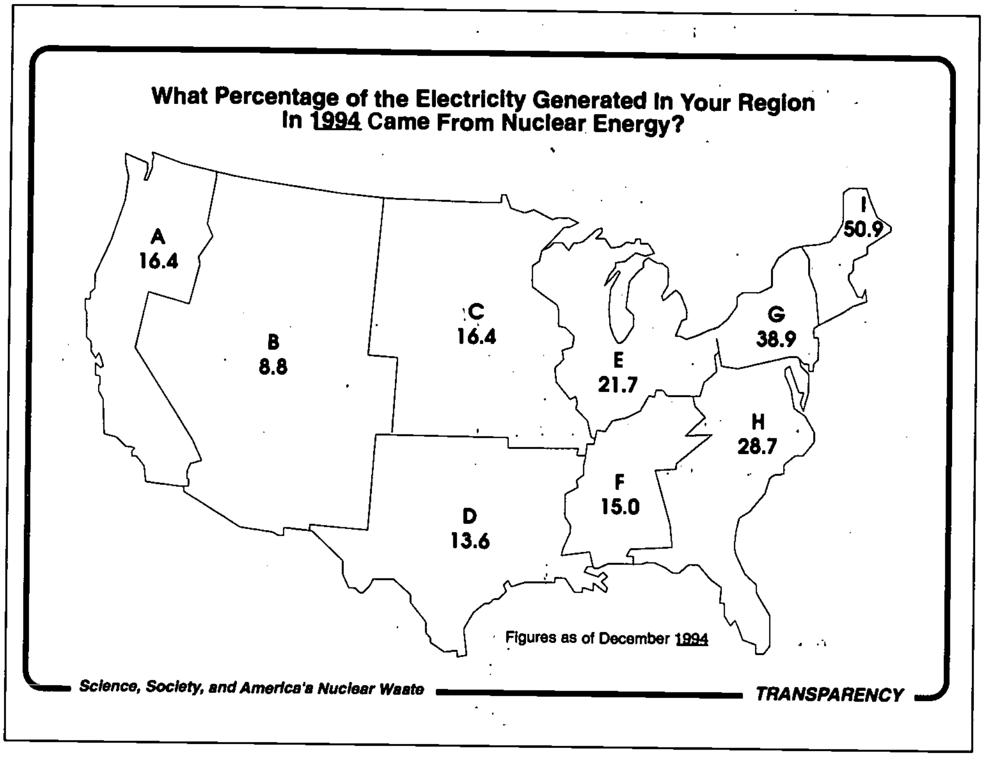
Science, Society, and America's Nuclear Waste **TRANSPARENCY**

Suggested Procedure:

1. **Energy and Electricity Review:** The attached optional review of energy and electricity has been provided for groups who will find a brief review helpful. If this reading lesson is not required, you may wish to proceed directly to #2. Concepts, objectives, vocabulary, etc. have not been prepared for this review.

2. The question of what to do with the accumulation of nuclear waste in the United States is a complex topic. Many aspects of this topic are controversial and scientific in nature. Students may feel that it has little or no relevance for them.

   You may wish to introduce the topic of nuclear waste by first establishing the relevance of the topic for students. One method of putting the subject of waste on a personal level and engaging students' interest is to have the classroom completely littered with classroom trash when students arrive for the first lesson in this course of study. Direct students to take their seats without any effort at cleanup other than to push aside anything that is an obstacle to finding and taking their seats. After students have been seated amongst the trash for a few minutes, ask if they feel that the condition of the classroom is a problem. If there is agreement that a problem exists, ask students what they feel should be done about it, and who is responsible for doing it.



Key to Regions listed on outline map entitled WHAT PERCENTAGE OF THE ELECTRICITY GENERATED IN YOUR REGION IN 1994 CAME FROM NUCLEAR ENERGY?

A	=	WA, OR, CA
B	=	AZ, CO, ID, MT, NV, NM, UT, WY
C	=	IA, KS, MN, MO, NE, ND, SD
D	=	AR, LA, OK, TX
E	=	IL, IN, MI, OH, WI
F	=	AL, KY, MS, TN
G	=	NJ, NY, PA
H	=	DE, DC, FL, GA, MD, NC, SC, VA, WV
I	=	CT, ME, MA, NH, RI, VT

After this brief exercise is concluded; ask them to identify other types of trash—specifically types related to energy. One way of encouraging students to think about energy-related wastes and their own contribution to the production of these wastes is to turn the classroom light switch off and then on again. Ask students to list the wastes that have probably been the products of producing the electricity that turned on the classroom lights. Relate the cleanup of wastes produced during energy production, especially spent fuel from nuclear reactors, to the "you make a mess, you clean it up" concept. Have students consider who is responsible for the cleanup and permanent disposal of the Nation's accumulating high-level nuclear waste: the present generation who created it or future generations who may be more advanced technologically?

Then begin a discussion of the following questions about energy and electricity use and generation. The transparencies about locations of nuclear powerplants and electricity are included to aid in your discussion of questions f, g, and h.

a. What are your activities for a typical school day (getting ready, traveling to school, during school, after school, and in the evening)?

b. Which involve the use of energy? Electricity?

c. How does the availability of electricity affect the manufacture of goods you and your family use? Food? Clothing? Transportation vehicles? Electronic goods? Other goods?

d. How does availability of electricity affect your family's income? How does it affect your education? Part-time jobs of other students or yourself?

e. What energy source or sources are used to generate the electricity you use?

f. What sources are used to generate electricity throughout the United States?

(1994 figures: coal – 56%; nuclear – 22%; natural gas – 10%; hydropower – 8%; petroleum – 3%; solar, geothermal, wood, wind, and waste – <1%.)

g. What role does nuclear energy play in producing our Nation's electricity?

h. What role does it have in producing electricity in your State or region?

i. Every energy source used to generate electricity has both benefits and problems. What are some benefits and problems associated with the major sources? Consider such factors as reliability of supply (including the effect on national security), air pollution, waste byproducts, cost, limited reserves, alternate uses of fossil fuels, and production hazards, etc. (Some examples are listed below, but this list is not meant to be exhaustive.)

Energy Source	Benefit	Problem
coal	a) domestic reserves b) relatively economical	a) hazardous to mine b) air pollution c) limited supply
uranium (nuclear)	a) concentrated energy source b) domestic reserves	a) hazardous to mine b) radioactive waste
water (hydroelectric)	a) renewable b) economical	a) building dams affects rivers and floods land b) few sites available for new dam construction c) supply affected by weather
oil	a) can be used when other sources not available	a) limited supply b) foreign dependence c) air pollution d) expensive e) alternate uses (transportation, petrochemicals etc.)
wind & solar	a) renewable b) environmentally desirable in most aspects	a) useful only when wind blows and sun shines b) more research needed to make it practical and economical
natural gas	a) domestic reserves b) clean burning	a) nonrenewable b) limited reserves
geothermal	a) renewable	a) geographically limited
tidal	a) renewable	a) geographically limited

3. Students should complete the review activity entitled *Electricity from Nuclear Energy* for this lesson in class.

4. You may wish to require students to clip newspaper and magazine articles regarding management of nuclear/hazardous waste and maintain a scrapbook throughout the course of study. Requiring that students document the source and date of their clippings may encourage them to read newspapers, periodicals, etc. on a routine basis. These student newsclip scrapbooks may be useful for enrichment activities appearing in Unit 3 regarding the Nuclear Waste Policy Act and Amendments.

Teacher Evaluation of Learner Performance:

Student participation in class discussion and completion of the activity entitled *Electricity from Nuclear Energy* will indicate understanding.

Enrichment:

Worldwide Waste Management, videotape - 20 minutes **(available free of charge by calling the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720)**

What Does Nuclear Waste Have To Do with Me?, p. 119
Regional Electricity Generation, p. 127

UPDATING ELECTRICITY GENERATION STATISTICS

Data for generation of electricity by the various energy sources is required for two activities in Unit 1, the activity entitled *Electricity from Nuclear Energy* (to complete the graph) and the enrichment activity entitled *Regional Generation of Electricity* (to complete the table entitled *Net Generation by Energy Source, Census Division, and State*, 1994). This data may be obtained from:

National Energy Information Center, EI-231
Forrestal Building, Room 1F-048
Washington, DC 20585
Telephone: (202) 586-8800
Hours: 9:00-5:00, M-F, Eastern Time

GENERATION OF ELECTRICITY

BACKGROUND

The production of electricity is generally referred to as generation, and is measured in kilowatt-hours. Gross generation is the amount of power produced by an electric powerplant (station), measured at the plant's terminals (that is, prior to the point at which the power leaves the station and is available to the system). Some of the electric power generated at a powerplant is used to operate equipment at the plant. Power used at the plant is generally between 1 percent (hydroelectric units) and 7 percent (steam-electric units). Net generation is the power available to the system (gross generation less use at the plant); however, it is greater than that available to consumers due to losses during transmission and distribution.

The energy sources used for producing electricity fall into two broad categories: nonrenewable (those that cannot be replaced once used) and renewable (those that are constantly replenished). The most common nonrenewable energy sources used for generation are the fossil fuels (coal, petroleum, and natural gas) and uranium. These energy sources account for more than 85 percent of the Nation's net generation. The renewable energy sources include the light or heat of the sun (solar); wind; the water in rivers, streams, or lakes (hydroelectric); heat from beneath the Earth's surface (geothermal); and organic waste (biomass) that is produced by either natural or technological processes.

The choice of generating technology and fuel used to produce electricity is of major importance to electric utilities because the goal is to provide the most cost-effective and most reliable electricity possible to consumers. A variety of factors influence the selection of technology and fuel; including the capital costs of the technology, operations and maintenance costs, environmental restrictions on the technology and use of the fuel, regulations affecting fuel use, the cost and availability of the fuel, and the availability of capacity associated with the type of fuel.

GENERATION FROM FOSSIL FUELS

COAL

Historically, most electricity in the United States has been generated using coal. After the Arab oil embargo of 1973, concerns over the availability of petroleum imports, increasing petroleum prices, and curtailments of natural gas made coal-fired generation even more important. In 1978, the passage of the Powerplant and Industrial Fuel Use and Natural Gas Policy Acts encouraged further use of coal by electric utilities. Although both Federal and State environmental laws and regulations exist, during the 1970's, renewed interest in environmental issues raised concerns about electric powerplant emissions, particularly from those burning coal. Bills were introduced during the 101st Congress to control acid rain or related air quality problems. Coal-fired generation continues to provide more than one-half of the Nation's total net generation of electricity. Most of the electricity production from coal is in the East North Central and South Atlantic Census Divisions, where substantial amounts of coal are mined.

PETROLEUM

During the early 1970's, electric utilities used petroleum extensively to generate electricity because it was a relatively inexpensive fuel. But after the 1973 embargo by the Organization of Petroleum Exporting Countries (OPEC) on petroleum exports to the United States, petroleum prices rose sharply. Further price increases occurred in 1979 and 1980 following the Iranian revolution and subsequent reduction in Iranian petroleum exports. Consequently, during the past decade, utilities have not built large petroleum-fired steam units. In addition, many utilities have either converted steam units to coal or switched fuels where dual-fired capability exists. Most of the utilities that still rely heavily on petroleum to generate electricity are located along the eastern seaboard and in California. Because of recent declines in petroleum prices, use of petroleum-fired capability has shown a resurgence.

NATURAL GAS

The demand for natural gas to heat homes and serve business and industry has historically taken priority over the demand of electric utilities under both Federal and State regulations. In the 1970's, many utilities were on occasion denied natural gas when available pipelines reached capacity in serving heating demand during the months from November to March (the peak heating season). By the middle 1970's, curtailments to electric utilities also occasionally occurred during the nonheating season as producers conserved supply in preparation for heating season demand. In the face of an attractive interstate price structure but deprived of supplies during many months of the year, utilities in the 1970's used relatively less expensive natural gas when it was available, then switched to other more expensive fuels when gas supplies were curtailed. Natural gas became more available to utilities with the passage of the Natural Gas Policy Act of 1978 and more frequent exemptions from the gas-use restrictions of the Powerplant and Industrial Fuel Use Act (Fuel Use Act) of 1978. Although lower petroleum prices during recent years have resulted in a decline in gas-fired generation, amendments to the Fuel Use Act in 1987 have created potential for additional future use of natural gas. The amendments to the Fuel Use Act in 1987 eased restrictions on the use of gas by removing a legal requirement to obtain an exemption for the construction of new gas-fired generating capability. The West South Central Census Division supplies more than half of the gas-fired generation in the country.

GENERATION FROM URANIUM - NUCLEAR ENERGY

Generation from nuclear power has generally increased since the 1950's, and this trend continues. Since 1984, nuclear plants have provided the second largest share of total U.S. generation of electricity, after coal-fired plants. Although no new nuclear units have been ordered since 1978, and the units ordered after 1974 were not built, many that were under construction have either been completed and entered service or will enter service in the near future. Licensing delays, questions about radioactive waste disposal, and concern about nuclear plant safety have slowed these units from entering service and are still major obstacles to additional growth in the use of this energy source for generating electricity. Most of the nuclear-powered generation comes from the Middle Atlantic, East North Central, and South Atlantic Census Divisions, where over 60 percent of the nuclear units in the country are located.

GENERATION FROM RENEWABLE ENERGY

HYDROELECTRIC

Water is currently the leading renewable energy source used to generate electric power. However, hydroelectric plants can operate only where suitable waterways are available, and many of the best of these sites have already been developed. Generating electricity using water has several advantages. The major advantage is that water is a resource which is renewable. A pumped-storage hydroelectric plant offers a second advantage in that these systems use electricity produced by other generators (generally those that serve baseload requirements) to pump water from one storage area (reservoir) to another. Later this water is allowed to flow from the higher reservoir to the lower one through the generator. In this manner, the same energy source (water) is used twice. Net hydroelectric generation statistics reflected in this report are derived by deducting the generation used for pumping (in-house use) from the total (gross) hydroelectric generation. Since water is renewable, it is a source of cheap power. In addition, because there is no fuel combustion, there is little air pollution in comparison with fossil fuel plants and limited thermal pollution in comparison with nuclear plants. Like other energy sources, the use of water for generation has limitations, including environmental impacts caused by damming rivers and streams, which affects the habitats of the local plant, fish, and animal life. Nearly 70 percent of the hydroelectric power in the United States is generated in the Pacific and Rocky Mountain States.

GEOTHERMAL, WIND, SOLAR, ETC.

Other renewable resources — geothermal (heat energy buried deep beneath the surface of the earth), wood, waste, wind, and the sun (solar) — are energy sources that are constantly replenished. These energy sources have received increased attention in recent years from utilities, but a limited number of such generating facilities are in use today. The major obstacles to their use are technology and cost. Currently, renewable resources (other than water) supply less than 1 percent of the Nation's electricity. Most of the electricity produced from this category is from geothermal power. Currently electric utilities operate geothermal plants in three States (California, Hawaii, and Utah). The Geysers, operated by the Pacific Gas and Electric Company, is the largest geothermal plant in the Nation. Only a few utilities operate units that produce electricity from wind and solar energy. Most of the electricity from these energy sources is produced from facilities in California. Wood and waste resources can be used to replace fossil fuels in utility boilers. To date, just a few electric generating units have been built that use wood as a primary fuel.

Source: Energy Information Administration, U.S. Department of Energy, Electric Power Annual 1992, *DOE/EIA-0348/92.*

ENERGY AND ELECTRICITY REVIEW

Energy in the form of electricity affects the daily life of nearly every American. The electricity we depend on is produced by many energy sources.

1.1 Energy in Our Lives

What is energy?

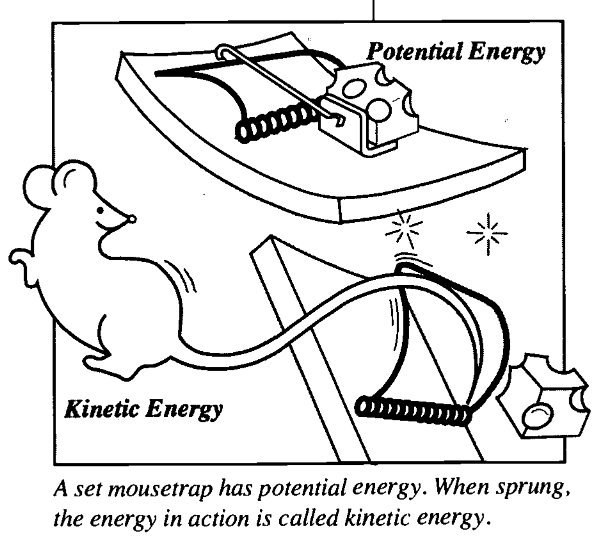
We use energy all the time. Whenever work is done, energy is used. In fact, energy is defined as the ability to do work. For instance, the amount of force needed to move an object may use up part or all of the available energy. All activities involve use of energy. Here are some of the things we need energy for:

- To power our factories and businesses
- To heat and light our homes and schools
- To run our appliances and machines
- To fuel our cars, airplanes, and ships
- To run television and films
- To use our telephones and computers
- To make our food and clothes

1.2 Kinetic and Potential Energy

What are the types of energy?

We can divide all energy into two basic types: *potential energy* and *kinetic energy.* Potential energy is stored energy that is waiting to be used. A mousetrap that has been set has potential energy; but if a hungry mouse accidentally trips it, the potential energy is changed into energy in action, known as kinetic energy. Heat, light, and motion all show that kinetic energy is present and is being used. Potential energy is often harder to detect. It must be changed into kinetic energy before we can use it.



A set mousetrap has potential energy. When sprung, the energy in action is called kinetic energy.

1.3 Energy Forms

What are the forms of energy?

There are many forms of potential and kinetic energy. These include mechanical, radiant, thermal, electrical, chemical, and nuclear.

- *Mechanical energy* is the energy of motion. Mechanical energy turns the wheels of a car.
- *Radiant energy* is the energy in light. The Sun's energy comes to us in this form.
- *Thermal energy* is heat energy, which is released when fuel is burned or a liquid is boiled.
- *Electrical energy* is the movement of *electrons,* one of the three basic particles that make up an atom. Electric current is the continuous flow of millions of electrons through a conductor, such as a copper wire.
- *Chemical energy* is the energy released when the chemical composition of materials changes. When baking soda is mixed with water the mixture bubbles. A chemical reaction is occurring and chemical energy is released.
- *Nuclear energy* is released when certain atoms (the smallest units of matter) change the makeup of their centers. Sometimes they split apart, or sometimes two centers are forced together.

Just as stored energy can be changed to active energy, the above forms of energy may be converted to one or more different forms. For example, when electrical energy reaches a lightbulb, the temperature of the bulb's center is changed to release both thermal and radiant energy as heat and light. Other examples of how energy forms change are given throughout this reading lesson.

1.4 Energy Sources

Where does energy come from?
What energy comes from the Sun?

Much of Earth's energy comes from the Sun in the form of radiant energy. Plants convert this energy to chemical energy by using a process called photosynthesis. This new chemical energy is stored in the form of sugars and starches, which provide energy for the plant to grow as well as for animals that eat the plant. When we burn plants such as trees, stored potential energy is released immediately in the form of thermal energy (heat) and radiant energy (light), which we call fire. Chemical energy is also released as the composition of the wood fuel changes to ash.

What causes wind?

Radiant energy from the Sun makes some parts of Earth warmer than other parts. Air surrounding these warmer surfaces is heated, causing it to rise. Cooler air from the less heated surfaces then flows in to replace the heated air that has risen. This flow of air is called wind.

Radiant energy from the Sun can also cause water to evaporate and turn into water vapor, which rises into the upper atmosphere where it forms clouds. The tremendous energy in storms and winds is actually caused by the Sun's radiant energy.

What are fossil fuels?

Over millions of years, countless plants and animals died and were slowly buried beneath the ground, where they were compressed. The chemical energy stored in them was concentrated in oil, coal, and natural gas. These fuels, created from animals and plants that lived long ago, are called fossil fuels. Fossil fuels currently provide about 70 percent of all our energy.

What are primary energy sources?

The four main, or primary, energy sources that we use today are:

- fossil fuel energy (coal, natural gas, oil);
- geothermal energy (heat from inside Earth);
- nuclear energy (uranium and plutonium); and
- solar energy (Sun).

What is a secondary source?

In addition to the primary energy sources, there are also secondary energy sources, which are produced by using the primary sources. Electricity is a secondary source of energy that can be produced by using any of the primary sources mentioned above. Water power, wind power, the wood we burn, and the food we eat are other secondary sources of energy that come from the primary source of the Sun.

What are nonrenewable and renewable sources?

Fossil fuels are thought of as primary energy sources, even though they originally took their energy from the Sun. Because it takes millions of years to make fossil fuels, there is a limited amount of these fuels on Earth. Consequently, fossil fuels are a nonrenewable energy source, and when we have used them up, they will be gone. Nuclear fuels, such as uranium and plutonium, are also nonrenewable energy sources. Geothermal and solar energy are called renewable sources because they cannot be used up.

1.5 Energy Conversion

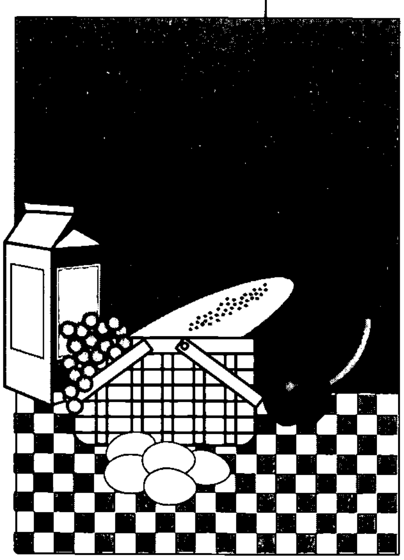
How do we convert energy from one form to another?

As shown earlier, energy can change from one form into another, but it cannot be created or destroyed. In fact, when we say that we use energy, we simply mean that we change it or harness it to do the work that we need done.

What is energy conversion?

We are always losing heat energy. This lost energy cannot be used again. It is similar to helium balloons that escape into the sky. They still exist, but we can no longer enjoy them. We must constantly put energy into things, or they will run down.

Changes in the types and forms of energy happen in hundreds of ways every minute. For instance, inside our bodies many different energy conversions take place constantly. Chemical energy in food enables us to walk and talk. In order to walk or run, and to keep our hearts beating, our bodies must convert the chemical energy in food into other forms of energy such as mechanical and thermal energy. Burning gasoline to power cars is another energy conversion process that we rely on. The chemical energy contained in gasoline is converted to mechanical energy.



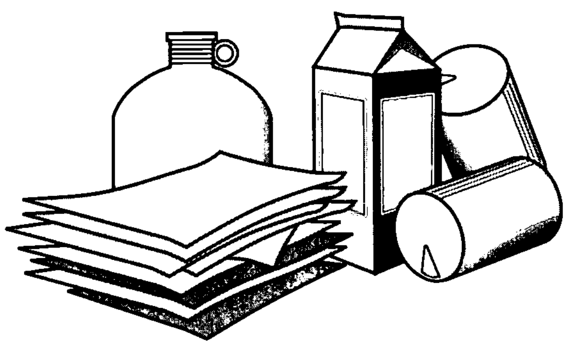
Our bodies convert the chemical energy in food into mechanical and thermal energy that allows us to function.

When we exercise, we also produce heat energy. You can easily feel this heat when you do a lot of work because your body will heat up. This happens because the process used to transform the chemical energy in your food into mechanical energy is not very efficient.

In fact, most energy conversion processes are not very efficient, and as a result, they lose energy to the environment. Only about a quarter of the energy that we use in our bodies and automobiles is transformed into mechanical energy. The rest is lost as heat. When a conversion process wastes a lot of energy, it is called inefficient.

The inefficient conversion and use of energy costs money and wastes nonrenewable resources. This is why people today are looking for ways to save energy by carefully using our energy sources and trying to convert energy as efficiently as possible.

1.6 Conservation



Recycling household waste is one way we conserve energy.

Saving energy is called conservation. Although conservation is not an energy source, we can use it to extend the length of time nonrenewable energy sources will be available in the future. Energy conservation is something that we all can practice by being careful about how much energy we use. Things that we can do to conserve energy include driving less and carpooling; insulating our homes; making sure thermostats are set correctly; recycling glass, metals, and paper; and turning off lights and appliances that are not being used. As conserving energy becomes more important, manufacturers are starting to make more efficient machines. Choosing automobiles and appliances that use energy efficiently is another way we can practice energy conservation.

How can energy be conserved?

1.7 Electricity

Shifting Energy Sources

While we once relied heavily on primary fossil fuels such as wood, fuel oil, coal, candles, etc., use of electricity proved more efficient, versatile, and even cleaner than these energy sources.

In the past, our energy needs for cooking, heating, and lighting were met using primary energy sources, most often by the burning of fossil fuels. Of all the forms of energy used today, electricity (a secondary source of energy) is the one we rely on most in our day-to-day lives. In fact, we are so accustomed to using electrical energy that we tend to take it for granted—until service stops and everything comes to a halt. One reason we use so much electricity is that it is our most versatile and adaptable form of energy. We use it at home, at school, and at work to run numerous machines and to heat and light buildings.

What is electricity?

What is electricity? To the scientist, it is the flow of electrons, usually through a wire. However, sometimes we see it in the sky as lightning or experience it as static electricity when hair is attracted to a comb or when someone takes off a sweater and there is a crackling sound.

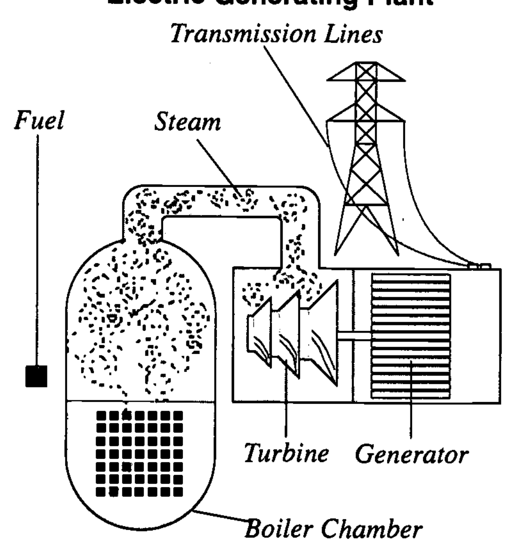
1.8 Generating Electricity

How is electricity produced?
From what sources is electricity generated?

Electricity is generally produced at a powerplant by converting one of the sources of energy into electricity. In the United States, the source is usually a fossil fuel (coal, oil, or natural gas), uranium, or water. Solar power, wind, *biomass,* or geothermal energy can also be used.

Most powerplants are very similar in several important ways. Most are designed to generate electricity by heating water to produce steam. The steam is then directed against the blades of a turbine, making it spin in the same manner air makes a windmill spin. A coil of wire attached to the shaft of the generator spins inside a magnet. This causes electrons to flow in the coil—and the flow of electrons is electricity.

Electric Generating Plant



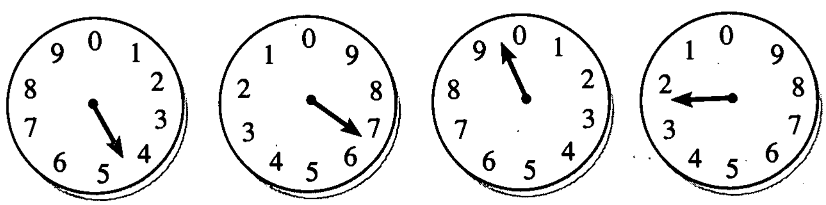
1.9 Transporting Electricity

How do we get electricity to the place where we use it?

The electricity produced in the generator is sent out over wires to homes, schools, hospitals, farms, and factories. Getting it there is not a simple job.

The generating plants and wires are owned and operated by about 1,000 different electric power companies all across the Nation. These companies must build powerplants, string wires or bury them underground, buy fuel for the plants, and hire workers to do all the jobs that must be done. As you can imagine, all that takes a lot of money.

That is why the users of electricity must pay to use it. Meters keep track of how much electricity travels from a power company's wires into homes, businesses, schools, and factories. The company sends a worker to read the meter to determine how much each user must pay and sends the user a bill.



Meter boxes measure how much electricity a consumer uses.

1.10 Electric Utilities

Companies that sell electricity are called utilities. A utility provides something useful or essential to the public, like electric power, gas, water, or telephone service. Because a utility provides an essential service to its customers, it has special duties. For instance, it must be able to supply all the electrical needs of its customers. A utility can't promise to deliver its product in two weeks the way some other companies can. Therefore, an electric utility must have generating plants, fuel, and sufficient power lines ready to do their jobs at any instant.

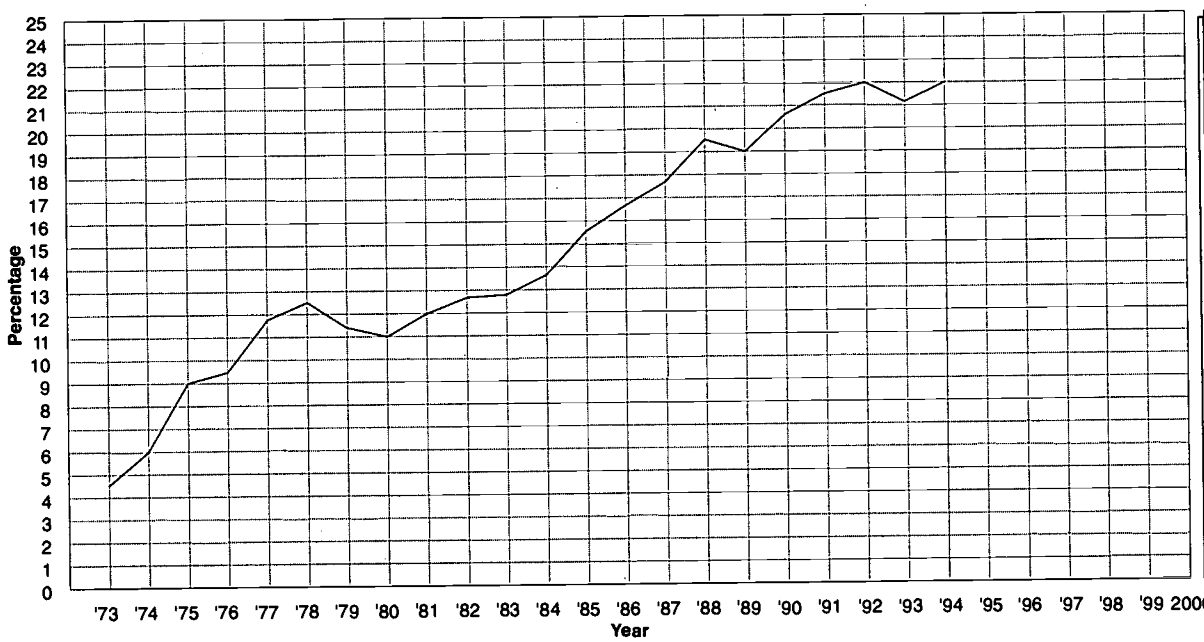
It would be wasteful and costly if more than one electric company served the same group of customers. Each company would have generating plants, fuel, power lines, and workers. So, a utility is assigned a specific area to serve, and no other electric company may sell electricity in that area. In exchange for that privilege, State and local governments regulate the utility. They tell a utility how much it can charge, what services it must provide its customers, and how much profit it can make.

Because an electric utility must serve the needs of the public, it must plan carefully so that it can produce enough electricity. Decisions made today must anticipate the public's need for electricity in the future. These decisions are very difficult because it can take as long as ten years to build a fossil fuel powerplant or fourteen years to complete a nuclear powerplant. This means that utilities must act on predictions of what customers will need in the future.

ELECTRICITY FROM NUCLEAR ENERGY

1. Briefly explain how electricity is important in your daily life.

   (Answers will vary)



Percentage by Year

1973	4.5
1974	6.1
1975	9.0
1976	9.5
1977	11.8
1978	12.5
1979	11.4
1980	11.0
1981	11.9
1982	12.6
1983	12.7
1984	13.6
1985	15.5
1986	16.6
1987	17.7
1988	19.5
1989	19.0
1990	20.6
1991	21.7
1992	22.1
1993	21.2
1994	22.0
1995	
1996	
1997	
1998	
1999	
2000	

2. The annual percentages of electricity produced by nuclear powerplants in the United States from 1973 to 1994 are given above. Graph the data above. Then in a sentence explain what the graph shows.

   (The graph shows that the percentage of electricity produced by nuclear powerplants has risen from 4.5% in 1973 to 22.0% in 1994.)

3. What do you think that the graph will look like in 2000? Why?

   (Answers will vary. Most experts expect nuclear power to continue to contribute at least 20%.)

4. Discuss the role nuclear energy plays in providing electricity for the United States. How does this affect you?

(Answers will vary)

5. How is electricity generation related to nuclear waste?

(Nuclear waste is a byproduct of generating electricity at nuclear powerplants. To have the electricity means we have the waste.)

NUCLEAR WASTE: WHAT IS IT? WHERE IS IT?

Purpose:

This lesson will help students differentiate among the four categories of nuclear waste: high-level waste, low-level waste, transuranic waste, and mill tailings. The lesson defines each category and describes how each type of waste is managed to protect the public and environment from hazards associated with radiation. The lesson focuses special attention on location of spent fuel and high-level waste from defense activities.

An optional review exercise has been provided in the event that a brief explanation of the fission process would be helpful. This review of fission may be used as an explanation, a review, or not at all, depending upon the needs of students.

Concepts:

1. A national problem exists because there is an accumulation of nuclear waste.
2. There are four major classifications of nuclear waste: high-level waste, low-level waste, transuranic waste, and mill tailings — all are radioactive.
3. Classification of nuclear waste depends on its source and the types and levels of radiation it emits.
4. Each type of nuclear waste is disposed of in a way that will <u>protect</u> the public and environment from hazards associated with radiation.
5. High-level waste in the form of <u>commercial</u> spent fuel is currently stored in <u>35</u> States.

Duration of Lesson:

Two 50-minute class periods

(Allow approximately 20 additional minutes if the optional review activity on fission is taught.)

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. list and define the four categories of nuclear waste;
2. state how each type of waste is or will be disposed of;
3. write a brief statement explaining the paradoxical relationship between the total volumes and radioactivities of nuclear wastes;
4. complete an outline map of the United States showing where spent fuel or high-level nuclear waste is stored and/or will be stored by the year 2000; and
5. discuss where spent fuel and/or high-level nuclear waste is currently stored in the United States.

Skills:

Analyzing, defining, describing, discussing, drawing conclusions, evaluating, interpreting charts and tables, mapping, synthesizing, writing

Vocabulary:

Ceramic pellets, commercial, compact, cubic meter, defense high-level waste, fission, fission products, fuel assembly, fuel rods, geographic, high-level waste, low-level waste, mill tailings, neutron, nuclear chain reaction, nuclear reactor, pie chart, radioactive, radioactivity, repository, spent fuel, transuranic, volume

Materials:

Reading Lesson
Nuclear Waste: What Is It? Where Is It?, p. SR-9

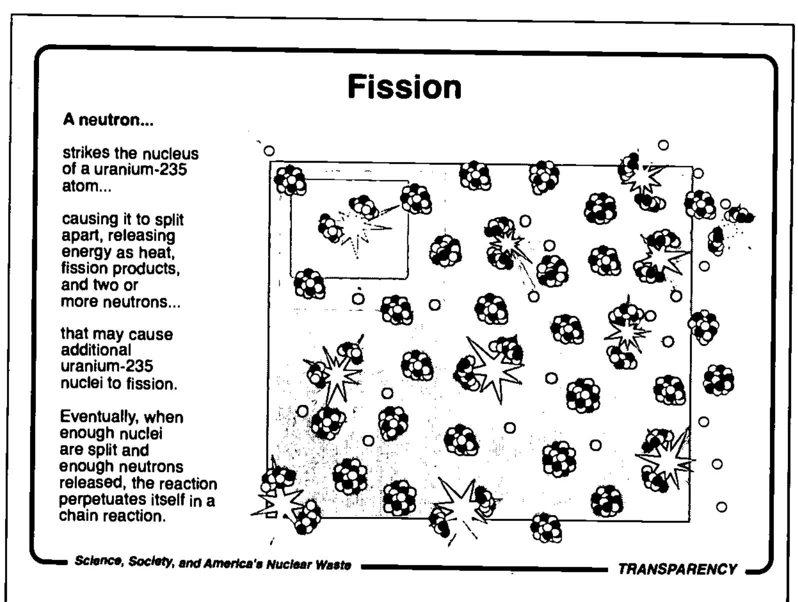
Activity sheets
Radioactive Wastes: Volumes and Radioactivities, p. 109
Nuclear Waste: What Is It? Where Is It?, p. 111
Geographic Distribution of Commercial Spent Fuel and Commercial and Defense High-Level Nuclear Waste, p. 115
(blank U.S. map and question/answer sheet)
Geographic Distribution of Commercial Spent Fuel and Commercial and Defense High-Level Nuclear Waste, p. 117

Transparencies
Fission, p. 83
Locations of Spent Fuel and High-Level Radioactive Waste Ultimately Destined for Geologic Disposal (map and matrix), pp. 85-105

Background Notes
Types of Nuclear Waste, p. 19
Storage of Spent Fuel, p. 21
Below Regulatory Concern (BRC) Materials, p. 25

Suggested Procedure:
Part I

1. The following optional review of nuclear fission has been provided for groups who will find a brief explanation of the fission process helpful. If this review is not required, you may wish to proceed directly to #2. Concepts, objectives, vocabulary, etc. have not been prepared for this review.



Fission Review:

a. Have students read or review the reading lesson entitled *Nuclear Waste: What Is It? Where Is It?* Direct student attention to the paragraph on fission products and transuranics, in particular.

b. Discuss reading lesson.

c. Show transparency of diagram of the fission process and discuss what is being illustrated.

d. Have students define or diagram the fission process and explain the terms fission products and transuranics.

e. Ask students to describe how fission products and transuranics relate to the fission process.

2. Review the reading lesson entitled *Nuclear Waste: What Is It? Where Is It?*

3. Discuss the various types/categories of nuclear waste and what classification of waste depends on.

4. Assign the Reading Review entitled *Radioactive Wastes: Volumes and Radioactivities*. You may wish to allow students to work together.

5. Review the activity sheet in class.

6. Be sure that students understand that most radioactive waste is low-level and does not require disposal in a repository. A small percentage of the total volume of radioactive waste is high-level, transuranic, or spent fuel and requires permanent disposal in a repository. The small volume of spent fuel and defense high-level waste contains the greatest percentage of radioactivity.

7. Have students begin working on the reading review for *Nuclear Waste: What Is It? Where Is It?* for homework.

Part II

1. Discuss the *Commercial Spent Fuel Storage – 1993 and 2003* Table in the reading lesson entitled *Nuclear Waste: What Is It? Where Is It?* showing the States where spent nuclear fuel and/or defense high-level waste is stored.

2. Distribute outline map of the United States and instruct students to fill in the map showing the three separate groupings indicated by the map key. Be sure to tell students to refer to information given in the introductory paragraph on the map activity and *Commercial Spent Fuel Storage – 1993 and 2003* Table in the reading lesson to help them make their groupings.

3. You may wish to review the map activity as a group prior to assigning the question/answer activity sheet.

4. Assign the activity sheet entitled *Geographic Distribution of Commercial Spent Fuel and Commercial and Defense High-Level Nuclear Waste*. Depending upon available time, you may wish to have students complete this as a group activity.

5. Discuss the responses when students have completed the activity sheet.

6. Have students write a short paragraph explaining the importance of this lesson.

Teacher Evaluation of Learner Performance:

Participation in class discussion, completion of reading reviews, outline map, and written assignment will indicate comprehension.

Enrichment:

Inventories of Spent Fuel, p. 43
Spent Fuel Inventories Number Line, p. 131
1993 Inventories of Spent Fuel by State, p. 133
Worldwide Nuclear Waste Management, p. 135
Low-Level Waste, p. 139
Low-Level Waste Compacts, p. 143
Low-Level Waste Number Line, p. 145
Low-Level Waste Received at Disposal Sites – 1993, p. 147

TYPES OF NUCLEAR WASTE

INTRODUCTION

The main emphasis of these curriculum materials is the development of a disposal system for spent fuel and high-level waste. To gain perspective, however, students should understand that spent fuel is not the only type of nuclear waste requiring disposal in the United States.

High-level nuclear waste results from defense activities. Low-level nuclear waste is generated at governmental and commercial sites. A type of nuclear waste called "transuranic waste" is also generated, primarily from defense activities. Transuranic nuclear waste is physically similar to low-level nuclear waste but is contaminated to a level requiring special handling, with long-lived radioactive elements higher than uranium in atomic number. A fourth type of nuclear waste requiring disposal is "mill tailings" generated by the recovery of uranium from mined uranium ore. Each type of waste will be disposed of in a way appropriate to its characteristics.

SPENT NUCLEAR FUEL

Spent fuel is fuel that has been used in and then withdrawn from a nuclear reactor. All spent nuclear fuel from commercial nuclear powerplants will be disposed of in a geologic repository for high-level waste. The U.S. does not reprocess commercial spent fuel. The spent fuel rods will be sealed in special metal canisters for disposal. In addition to commercial spent fuel, there is some Department of Energy-owned spent fuel and high-level waste, some Navy reactor spent fuel, and high-level waste that results from non-DOE research reactors. Ultimately, all of this spent fuel and high-level waste is destined for geologic disposal.

HIGH-LEVEL NUCLEAR WASTE

High-level nuclear waste is generated by the chemical reprocessing of spent nuclear fuel to recover uranium and/or plutonium. All high-level nuclear waste will be disposed of in a geologic repository. The waste, in liquid form after reprocessing, will be solidified into a glass or ceramic form and will be sealed in metal canisters for permanent disposal. In 1985, President Reagan made the decision that separate repositories for the disposal of defense high-level waste and commercial spent fuel and high-level waste are not necessary.

LOW-LEVEL NUCLEAR WASTE

All radioactive waste other than spent fuel, high-level waste, and transuranic waste is considered to be low-level waste. Low-level nuclear waste is generated at commercial nuclear powerplants, hospitals, industrial and agricultural facilities, and academic institutions. Depending upon its activity, the low-level waste is disposed of in various forms of shallow-land burials.

Low-level waste from all activities, except Federal defense or research and development activities, will be the responsibility of the State in which the waste is generated. Low-level waste will be disposed of in facilities developed by individual States or groups of States known as compacts. Specially designed aboveground facilities and shallow-land burial are being considered by States and compacts.

Low-level waste from defense activities and research and development activities of the Federal Government will be disposed of at Federal disposal sites, primarily where the waste is generated. It will not be disposed of at the commercial disposal sites States are responsible for.

TRANSURANIC NUCLEAR WASTE

Transuranic waste is physically similar to low-level waste but is contaminated with transuranic elements to a level requiring geologic disposal. Although the total activity of transuranic wastes are no greater than certain low-level wastes, geologic disposal is considered necessary because they lose radioactivity very slowly and remain hazardous for thousands of years.

Transuranic wastes result primarily from defense activities. Some transuranic waste is being stored in surface facilities but current plans call for most of this waste and transuranic waste generated in the future to be ultimately placed in deep geologic storage at the Waste Isolation Pilot Plant (WIPP) facility in New Mexico. The transuranic waste disposed at the WIPP facility will be in the form of solids sealed in metal canisters.

MILL TAILINGS

Mill tailings are naturally radioactive rock and soil that are byproducts of mining and milling uranium. They are generally disposed of where they are generated, at facilities where uranium ore is mined and milled. The Federal Government has responsibility for mill tailings at inactive milling facilities. Companies currently milling uranium must make sure their disposed tailings are in compliance with government and State regulations.

STORAGE OF SPENT FUEL

INTRODUCTION

After being removed from the reactor, the spent fuel is stored under water in a storage pool at the reactor site. Typically, about one-third of the fuel assemblies in a reactor are removed and replaced by fresh fuel once every fueling cycle. At present, utilities are using fueling cycles of 12 to 24 months, depending on the reactor type, fuel, and operating conditions.

The storage pools at reactors are designed to store a limited amount of spent fuel. Ultimately, if there is not enough space in the storage pool to accept additional spent fuel, the utility must either remove from the pool some of the spent fuel that has been stored there or stop operating the reactor. In some cases, if the utility is operating nuclear powerplants at several different sites, the spent fuel removed from the pool may be shipped to another site for storage in a pool that has space. This option is not available for most reactors, and it provides only a temporary solution.

A number of utilities may be faced with a shortage of storage capacity for their spent fuel. The storage capacity can be increased by increasing the capacity of the storage pools or by providing dry storage outside the pool. In-pool capacity can be increased by changing the racks that hold the spent-fuel assemblies inside the pool or by consolidating the fuel rods into more compact arrays.

INCREASING IN-POOL CAPACITY BY RERACKING

Initially, the racks that hold spent-fuel assemblies in the storage pools were not designed to maximize the amount of spent fuel that can be stored in a pool. (When the pools were built, it was expected that the spent fuel would be removed and reprocessed.) The storage capacity of a spent-fuel pool can be increased by *reracking* the pool. Reracking means changing the arrangement of the racks that hold the spent fuel assemblies.

SAFETY FACTORS IN RERACKING

According to the Nuclear Regulatory Commission (NRC), facilities for spent fuel storage must be designed to prevent, by a safe margin, the occurrence of a "critical mass," even under accident conditions. In a nuclear reactor, the fissionable fuel is arranged in such a way that, under operating conditions, a critical mass is achieved in the fuel and a chain reaction occurs in which one neutron from each fission causes another atom to fission. The reactor is then said to have "gone critical" or to have achieved *criticality*. An inadvertent criticality in a spent fuel storage facility could overheat the fuel, cause significant damage to the fuel rods, increase the emission of radiation, and possibly release excessive amounts of radioactive elements.

In terms of criticality, the amount of fuel that can be stored inside a given storage pool depends on both the geometric arrangement of the fuel and on the materials used in the storage racks. In reracking, the single most important factor is the spacing between the spent-fuel assemblies. Usually the racks provide more spacing than is needed to preclude a potential for criticality, and therefore, more spent fuel can be accommodated if the standard racks are replaced with racks providing closer spacing.

The ability of the pool to safely support the weight of additional spent fuel is also considered. Other factors that are considered are the ability to meet the NRC's seismic criteria, heat generation and pool cooling, shielding from radiation, water cleanup, and ability to accommodate in-service inspection.

Reracking is usually the initial choice of utilities for increasing storage capacity at reactor sites. The technology for reracking is fully developed and reracking is usually the least expensive of all available options.

INCREASING IN-POOL CAPACITY BY ROD CONSOLIDATION

Rod consolidation is another option for increasing in-pool capacity. It involves mechanically removing the fuel rods from the hardware that holds them together in a spent fuel assembly and rearranging them in a more compact array inside a metal canister. At-reactor consolidation is performed under water in the spent fuel storage pools. As with reracking, structural strength and seismic characteristics of the storage pool are considered to determine whether this option can be used. With consolidation, potential for neutron chain reaction is lower than it is in reracking for the storage of intact spent-fuel assemblies. This is because a closely packed array does not enhance a nuclear chain reaction.

DRY-STORAGE CONCEPTS

In addition to expanding in-pool capacity, the capacity of at-reactor storage can be increased by providing dry storage. Dry storage can be in various types of casks, modules, or vaults located outside the pools. Such dry-storage concepts include metal casks, concrete casks, horizontal concrete modules, modular concrete vaults, and dual-purpose casks. Dry storage can accommodate either intact spent-fuel assemblies or canisters of consolidated spent fuel.

AGE OF SPENT FUEL FOR DRY STORAGE

All spent fuel will be stored first in the spent fuel pool where its radioactivity and rate of heat generation diminish. The spent fuel that would be stored in any of the dry-storage systems would be fuel that has been stored in a spent fuel pool for at least one year, and most likely several years.

Thus, if dry storage is to be used at a reactor site where the spent fuel pool is filled to capacity, it will be necessary to remove from the pool spent fuel that has been stored under water for at least a year and transfer it to dry-storage facilities. The spent fuel could be removed by loading it into a storage cask under water inside the pool, lifting the loaded storage cask from the pool, and transferring the cask to the dry-storage facilities. A transfer cask could be used for removing the spent fuel from the storage pool, moving it to the dry-storage facilities, and loading it into the dry-storage cask, module, or vault. Removal and transfer operations would be scheduled to take place when no other operations are required or are under way in the storage pool.

LICENSING CONSIDERATIONS

Except for the consolidation and storage of small amounts of spent fuel, the methods for increasing at-reactor storage will require licensing by the Nuclear Regulatory Commission (NRC). Licensing considerations are important because licensing can be a long process.

Both spent fuel pool storage and dry storage can be used at the same reactor site, but they are subject to different NRC regulations. This is because the spent fuel pool is considered to be an integral part of the nuclear powerplant. Dry storage facilities, on the other hand, are independent facilities that are not considered to be an integral part of the plant.

Source: Final Version Dry Cask Storage Study (DOE/RW-0220), February 1989.

BELOW REGULATORY CONCERN (BRC) MATERIALS

The Nuclear Regulatory Commission (NRC) has been concerned about the large amounts of low-level waste, some containing inconsequential amounts of radioactivity, being shipped to licensed low-level disposal facilities. The problem is coupled with the question of what to do with other slightly radioactive materials. Accordingly, on June 27, 1990, the NRC published the criteria it will use to determine whether such materials are "below regulatory concern" (BRC) and can be handled or disposed of as non-radioactive materials.

The materials and activities covered by the "guidelines" are: 1) very low-level radioactive waste; 2) decommissioned and decontaminated facilities; 3) recycled materials; and 4) consumer products.

The present policy statement by the NRC does not reflect a decision to exempt any material from regulatory control but simply provides the criteria that determine whether an exemption can be granted. A request for exemption must first be made. Then, after a review process and the establishment of appropriate constraints, if the material satisfies the criteria, an exemption can be granted.

According to Robert Bernero, Director of the NRC Office of Nuclear Material Safety and Safeguards, "The heart of the guidelines are the BRC dose criteria." The commission applied an upper limit of 10 mrem per year exposure to individuals involved in activities requiring a limited number of people. Where there is a widespread distribution of exempt materials, the limiting exposure is lowered by a factor of 10 to 1 mrem/yr. The collective exposure criterion was set at 1,000 person-rem per year. This is equivalent to one million individuals receiving 1 mrem/yr or 100,000 individuals receiving 10 mrem/yr.

It is obvious that there is some level of radioactivity in materials below which regulation is not required and above which it is. For example, most foods have some radioactivity, mainly potassium-40 and carbon-14 (see *Sources and Characteristics of Ionizing Radiation*, Unit II of this curriculum). Brazil nuts are the world's most radioactive food; the brazil nut endotherm has an alpha activity from radium-226, radium-228, and their decay products as high as 1.4 disintegrations per second per gram. Some consumer products, such as smoke detectors, lantern mantles, luminous-dial watches, etc., also have small amounts of radioactivity but not enough to require regulated disposal.

Nonetheless, the NRC announcement caused some public and corporate concern. It will be interesting to see how the first applications for BRC exemptions turn out.

Source: Federal Register, Vol. 55, No. 128, July 3, 1990, P. 27522.

NUCLEAR WASTE: WHAT IS IT? WHERE IS IT?

The large powerplants that supply our energy needs today create wastes as byproducts of using primary and secondary energy sources. These wastes can range from the solid ash produced in coal-burning plants to exhaust gases that contribute to air pollution and acid rain. Waste that results from using radioactive materials is nuclear waste. The U.S. Government has programs underway to provide for the safe permanent disposal of all types of nuclear waste.

1.11 Sources and Types of Nuclear Waste

Where does nuclear waste come from?

Nuclear waste comes from five major sources:

1. all steps involved in using nuclear energy to produce electricity;*
2. defense activities;
3. hospitals, universities, and research labs;
4. industry; and
5. mining and milling of uranium ore.

What are the four main categories of nuclear waste?

There are four basic types of nuclear waste: high-level waste, low-level waste, transuranic waste, and mill tailings. Classification of waste depends on its source, its level of radioactivity, and its potential hazard (or how likely it is to cause harm).

High-Level Waste

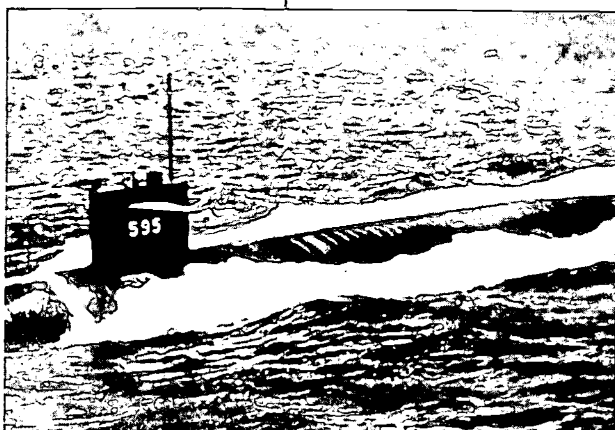
Radioactive — Giving off energy in the form of particles and rays by changes in the nucleus of an atom. *Radioactive materials emit energy when they undergo decay.*

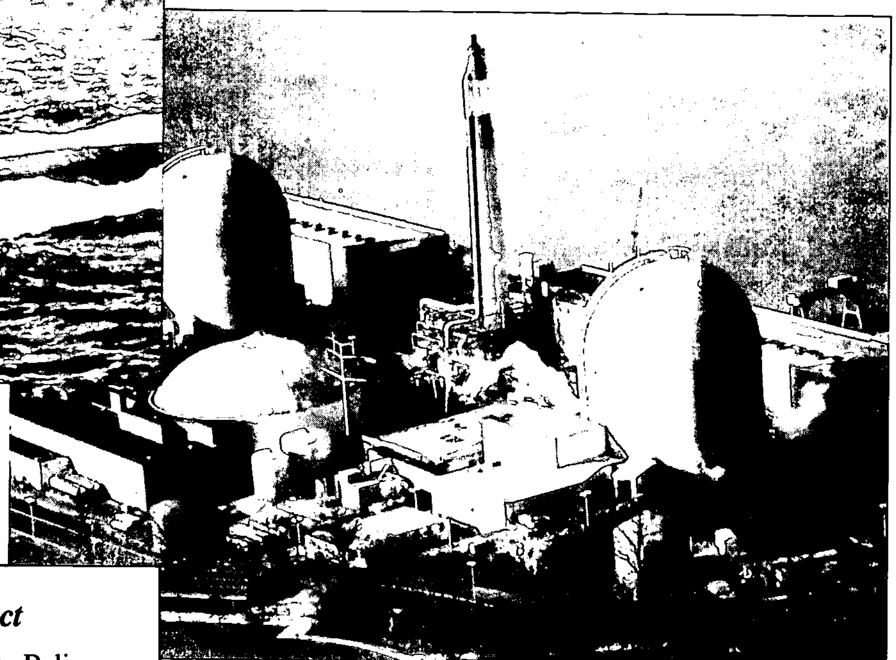
What is high-level waste?

High-level nuclear waste is the most radioactive category of nuclear waste. It includes *spent fuel* (used fuel) from nuclear powerplants and some wastes from our Nation's defense activities. Both spent fuel and high-level defense waste are now in storage awaiting disposal. Some radioactive elements in high-level waste lose radioactivity (decay) rather quickly. Others remain radioactive for thousands of years.

**the nuclear fuel cycle*

High-level waste is handled using remote control equipment. Operators of the equipment work behind heavy protective shielding. This type of waste is transported in heavily shielded containers.





Defense activities and nuclear powerplant operations produce nuclear waste.

Nuclear Waste Policy Act

Congress passed the Nuclear Waste Policy Act of 1982 and the Nuclear Waste Policy Amendments Act of 1987 to provide for safe disposal of high-level nuclear waste. These laws require the U. S. Department of Energy (DOE) to dispose of this kind of nuclear waste in a deep underground facility called a geologic *repository*. In the 1987 law, Congress directed DOE to perform an intense study (called *site characterization*) of Yucca Mountain, Nevada. The purpose of site characterization is to determine whether Yucca Mountain is suitable for a repository.

Low-Level Waste

Low-level nuclear waste usually contains only a small amount of radioactivity within a relatively large amount of material. It is far less hazardous or dangerous than high-level waste. Most low-level waste does not require extensive protection. However, for certain low-level waste, some shielding may be necessary.

What is low-level waste?

Hospitals, nuclear powerplants, research labs, and many industries produce low-level waste. Also, some of the waste produced by defense activities is low-level waste. Low-level waste from research and medical activities may include commonly used equipment such as empty containers, rags, papers, filters, broken tools, and used protective clothing. These are examples of the kinds of things that become low-level waste from energy production activities.

Where does low-level waste come from?

Low-level radioactive waste from a nuclear powerplant includes such things as filters, clean-up rags, lab supplies, and discarded protective clothing.

Low-level wastes are placed in containers and then buried at special landfills licensed by the Federal Government. Two sites were in use by 19 States on September 30, 1994: Barnwell, South Carolina, and Hanford, Washington. Federal law allows these sites to limit access for disposal to regional wastes. Other States are to develop disposal capabilities, but some have not met a January 1, 1993, deadline. Barnwell is scheduled for closure on December 31, 1995.

How is low-level waste disposed of now? Where?

Who will be responsible for disposal of low-level waste in the future?

Low-Level Radioactive Waste Policy

The amended Low-Level Radioactive Waste Policy Act of 1980 set the policy for disposal of low-level nuclear waste. By law, each State is responsible for providing for the safe disposal of the low-level waste produced within the State. (The Federal Government will be responsible for any low-level waste resulting from Federal activities.) The State may form a *compact* with other States to provide a regional facility for every member State to use. Congress must approve these compacts. Once approved, a compact can refuse to accept low-level waste from non-members. If it prefers, a State may operate its own disposal facility with the right to exclude waste from other States.

Transuranic Waste

What is transuranic waste?

Like low-level waste, transuranic waste is mostly discarded clothing, rags, equipment, containers, tools, etc. Like low-level waste, it emits less penetrating radiation than high-level waste. In fact, some transuranic waste has no more radioactivity than certain low-level waste. However, unlike low-level waste, transuranic waste contains elements with very long half-lives. Therefore, these elements decay (lose radioactivity) slowly and remain radioactive for thousands of years.

This cutaway view of barrels of transuranic waste shows how clothing, equipment, and solidified sludge are packaged in a dry, solid form.

Where will transuranic waste be disposed of?

Most transuranic waste results from reprocessing nuclear fuel and making plutonium weapons as part of the Nation's defense activities. Some of this kind of waste is now being stored in facilities located above ground, but plans call for it to be disposed of in a repository deep under ground. The U.S. Government plans to test geologic disposal of transuranic waste at the Waste Isolation Pilot Plant (WIPP) facility in New Mexico. The type of rock at the WIPP facility is bedded salt.

Mill Tailings

What are mill tailings? Are they hazardous?

The fuel used at a nuclear powerplant comes from uranium ore, which is found in the ground. Ore containing uranium is mined and then milled (crushed and treated to separate and remove the uranium). The leftover rocks and soil are mill tailings. The tailings contain a small amount of radium that decays to radon, a radioactive gas. Radon can be harmful to our health if we are exposed to it in concentrated amounts. For this reason, the mill tailings are covered over with enough soil to protect the public and the environment.

1.12 Spent Fuel

The fuel for nuclear powerplants is uranium oxide formed into ceramic pellets. Each pellet is about 3/8-inch in diameter and 1/2-inch long—about the size of the tip of your little finger. The pellets are stacked and sealed in fuel rods—hollow metal tubes about twice the thickness of a pencil and about 12 feet long. Groups of fuel rods are spaced and bolted together to form a fuel assembly. A fuel assembly contains about 200 fuel rods. Finally, fuel assemblies are loaded into the reactor. The number of fuel assemblies varies and depends on the design of the reactor.

Reactor — The part of a nuclear powerplant where fission takes place. *Fission takes place in a reactor, which is basically a machine that heats water.*

Over time, as the reactor operates, the fuel becomes less efficient. After about three years in the reactor, the fuel assemblies are no longer doing their job. At this point they are called spent fuel. Spent fuel must be removed and disposed of in a safe way.

What is spent fuel?

1.13 Fission

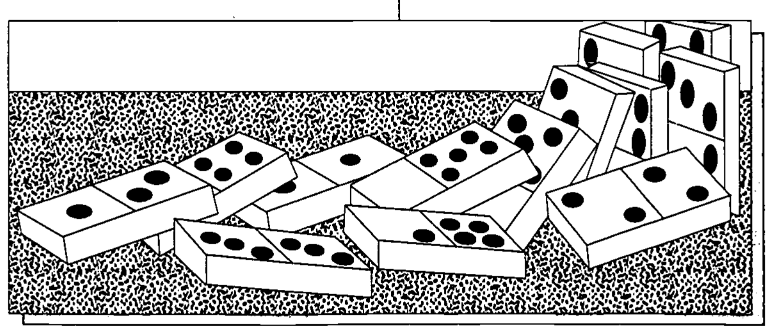
What is fission?

Coal, oil, and natural gas burn. Nuclear fuel does not burn. So how does nuclear fuel get "used up"? How does it produce the energy in a nuclear powerplant? The answer is by a chain reaction. Uranium atoms in nuclear fuel produce the energy needed for a nuclear powerplant by splitting (or "fissioning") into smaller atoms. In the process, they release a great deal of heat. In fact, one ton of nuclear fuel will provide about 100,000 times as much electrical power as that provided by burning one ton of coal.

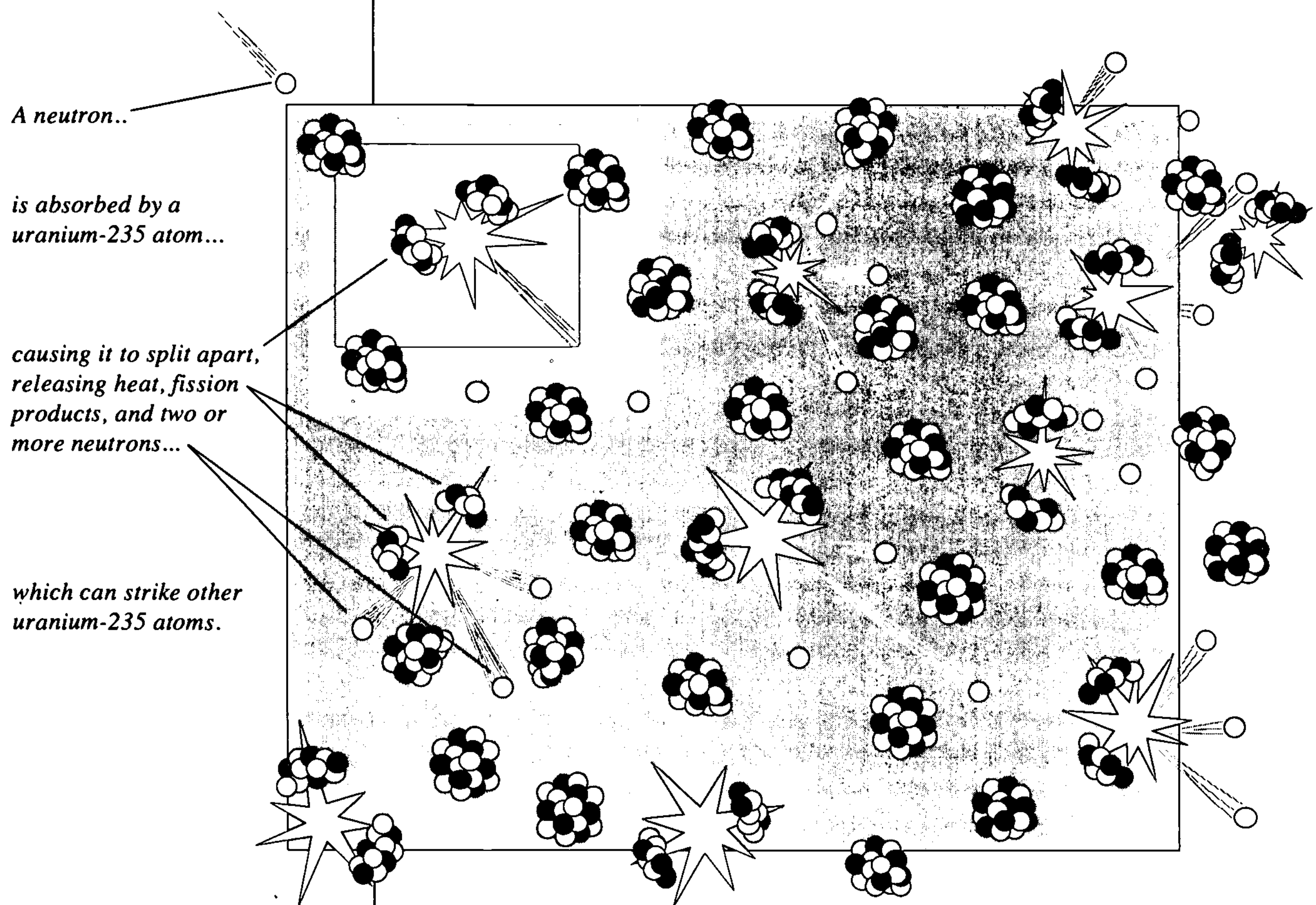
A Chain Reaction

If you knock over the first domino in a line of standing dominos, the second one will fall as the first one hits it. Then the next one will fall as the second one hits it...and so on down the line.

Fission is the process in which a uranium atom absorbs a *neutron* and then splits into two smaller atoms, releasing a relatively large amount of energy and one or two neutrons. These neutrons in turn can cause other uranium atoms to fission, releasing more energy and still more neutrons. Eventually, a nuclear reaction is achieved in which only one neutron from each uranium atom that



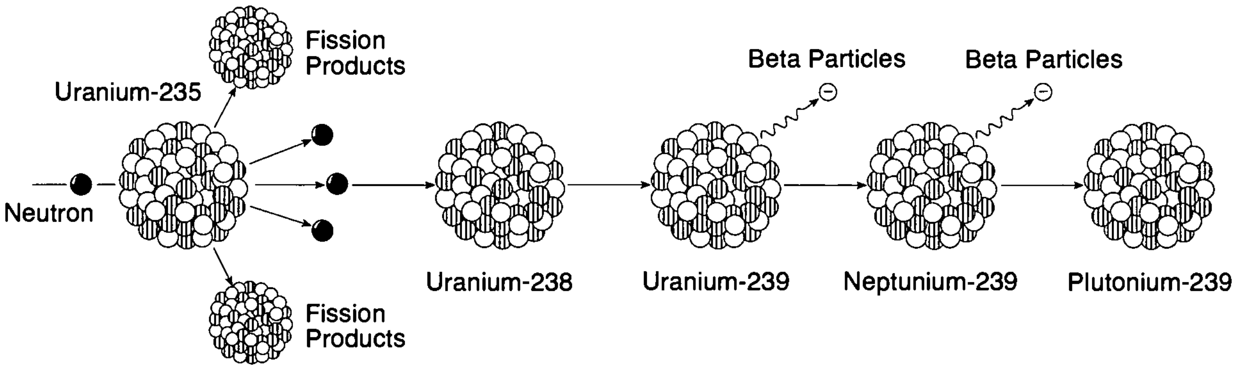
fissions causes another uranium atom to fission. Such a nuclear reaction is a "nuclear chain reaction." The nuclear chain reaction produces the energy that is converted to electricity at a nuclear powerplant.



What are fission products?

The smaller atoms produced by the fissioning uranium atoms are called "fission products." Fission products are very radioactive. They make up the part of high-level waste that loses radioactivity relatively fast.

The Formation of Plutonium



1
A uranium-235 atom absorbs a neutron and splits into two lighter atoms called fission products, releasing heat energy and two or more neutrons.

2
If a uranium-238 atom absorbs a neutron, fission rarely occurs.

3
Instead, it forms uranium-239. Through the process of radioactive decay...

4
It transforms first to neptunium-239, and then through an additional decay to...

5
plutonium-239. The transformation takes about 2 days.

What are transuranics?

There are two types of uranium atoms in nuclear fuel. When a uranium-235 atom absorbs a neutron, it fissions. Uranium-238 does not. When a uranium-238 atom absorbs a neutron, it is converted into a radioactive element called a *transuranic* element (a transuranic element has a higher atomic number than Uranium on the periodic table of elements). As uranium-238 atoms absorb neutrons, more and more of these transuranic elements form. The transuranic elements make up the portion of high-level waste that loses radioactivity very slowly. They cause spent fuel and high-level waste to remain radioactive for thousands of years.

Why does the fission reaction become less efficient?

Where does all this activity take place? It takes place inside the fuel rods. Fission products and transuranic elements accumulate within the fuel rods. Gradually, the uranium-235 in the nuclear fuel is almost used up and the nuclear chain reaction becomes less efficient. That's when the fuel assemblies (now spent fuel) must be removed and replaced with fresh fuel.

1.14 Spent Fuel Storage

More that 20 percent of the Nation's electricity is produced by more than 100 nuclear powerplants located around the country. As of 1993, nearly 28,000 metric tons (27,552 tons) of spent fuel were in storage.

Where is spent fuel stored?

Spent fuel is stored in specially treated water in a deep, steel-lined, concrete pool inside a building at the powerplant. Here it begins to cool and becomes less radioactive as it decays.

Commercial Spent Fuel Storage – 1993* and 2003

State	1993	2003
	(Metric Tons of Uranium)	
Alabama	1,334	2,130
Arizona	430	1,125
Arkansas	554	884
California	1,263	2,181
Colorado	15	15
Connecticut	1,169	1,752
Florida	1,320	2,048
Georgia	915	1,713
Idaho	51	51
Illinois	4,154	6,701
Iowa	231	360
Kansas	194	420
Louisiana	318	790
Maine	426	580
Maryland	578	882
Massachusetts	431	489
Michigan	1,149	1,951
Minnesota	610	930
Mississippi	299	590
Missouri	242	470
Nebraska	350	610
New Hampshire	63	295
New Jersey	1,080	1,855
New York	1,792	2,588
North Carolina	1,460	2,311
Ohio	395	810
Oregon	358	859
Pennsylvania	2,284	4,250
South Carolina	1,684	2,923
Tennessee	409	1,066
Texas	360	1,155
Vermont	365	502
Virginia	1,088	1,804
Washington	191	363
Wisconsin	779	1,128
Total	**28,312**	**48,045**

**Most recent data available at time of printing.*
Source: Nuclear Fuel Data: Form RW 859 (1993). *U.S. Department of Energy, Washington, DC. (Sum of entries may not equal totals due to rounding process.)*

Some utilities are now using dry storage to increase their storage space. (Dry storage is discussed further in Unit 4.)

During the first three months of storage, spent fuel loses about 50 percent of its radioactivity. In one year, it loses about 80 percent. In 10 years, radioactivity is reduced by 90 percent. But the remaining 10 percent ***could be*** a danger to health and the environment for thousands of years. (Some countries reprocess their spent fuel. The U.S. reprocessed a small amount of commercial spent fuel in the early 1970's, but currently does not do so.)

How does spent fuel change during storage?

1.15 Storage of Defense High-Level Waste

As part of our country's national defense program, nuclear materials are used for nuclear weapons. About 9,000 metric tons (8,856 tons) of defense high-level waste are stored temporarily at three U.S. Department of Energy sites: Savannah River Plant in Aiken, South Carolina; Idaho National Engineering Laboratory in Idaho Falls, Idaho; and U.S. Hanford Reservation in Richland, Washington.

How much defense waste is there?

The Nuclear Waste Policy Act required the President to decide whether to dispose of defense high-level waste in the same repository as spent fuel. In 1985, President Reagan accepted the recommendation of the Secretary of Energy to dispose of defense high-level waste in the repository planned for spent fuel from nuclear powerplants.

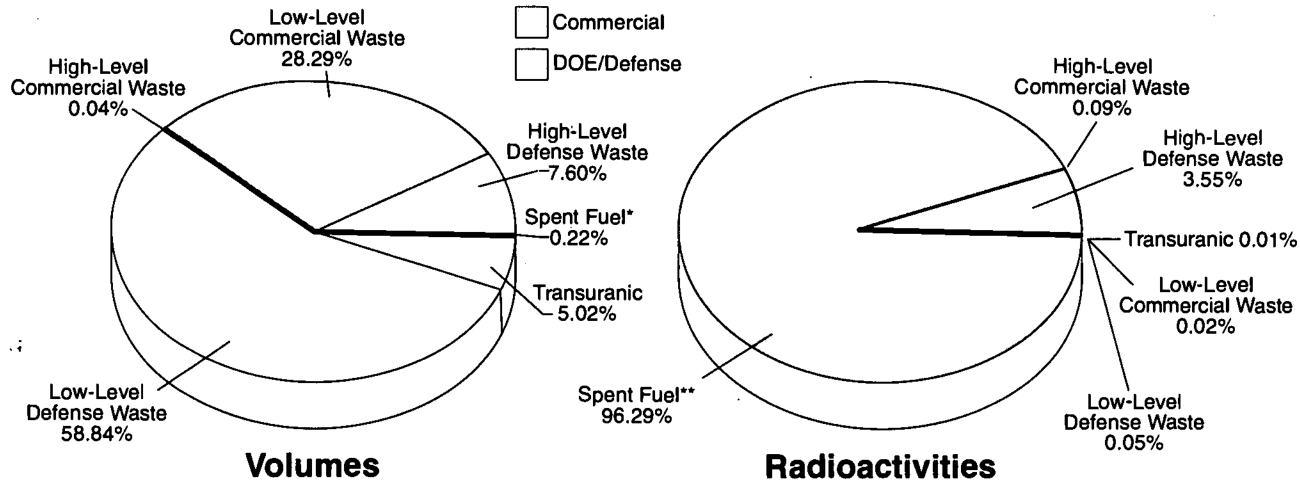
Where will high-level waste from defense activities be disposed of?

1.16 Volumes and Radioactivities

The *volume* of waste does not tell you its level of radioactivity. Both the volume (space occupied) of waste and how much radioactivity it contains are important. A large volume of waste with little radioactivity presents less hazard than a smaller amount of waste with more radioactivity. For example, spent fuel is far less than 1 percent of the volume of radioactive waste, but it contains almost 95 percent of the total radioactivity. On the other hand, low-level waste is nearly 86 percent of all radioactive waste by volume, but contains less than one-tenth of one percent of the total waste radioactivity.

Why is it important to consider both the volume of waste and the level of radioactivity?

Radioactive Wastes: Volumes and Radioactivities (1993)



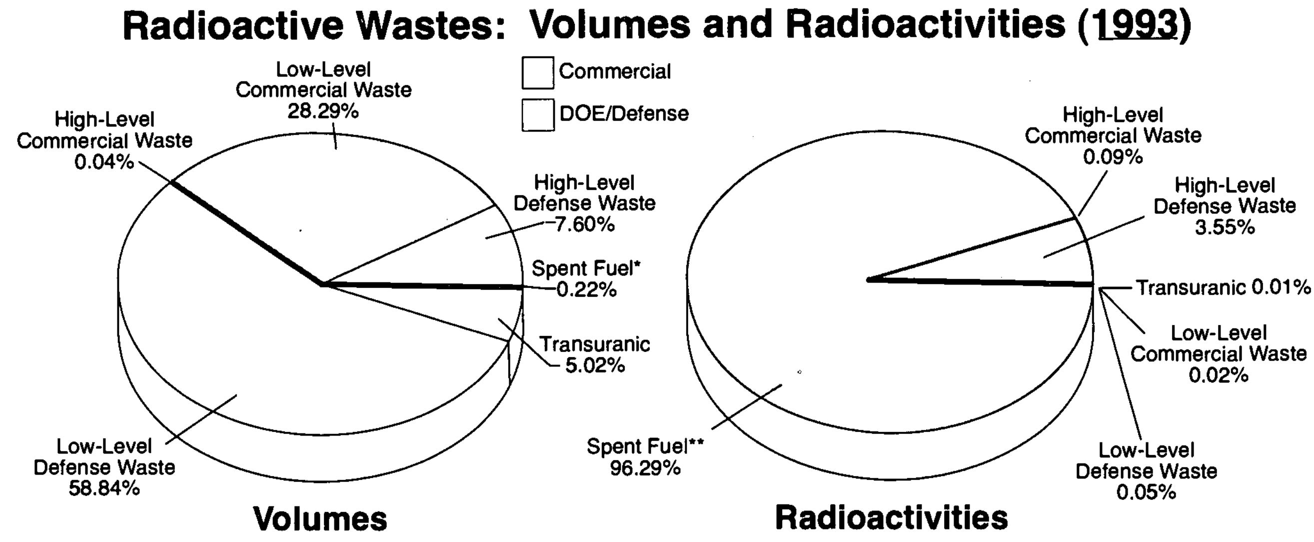
**Includes spacing between fuel assembly rods. DOE/Defense Program spent fuel to be reprocessed is not shown.*

***DOE/Defense Program spent fuel to be reprocessed is not shown.*

Source: Calculated from data presented in Table 0.3 of *U.S. Department of Energy*, Integrated Data Base Report - 1993: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics *(DOE/RW-0006, Rev. 10), December 1994*.

1.17 High-Level Waste Focus

As you now know, there are four different types of nuclear waste. Each type is stored and will be disposed of in a way that protects people and the environment. From this point on, our main focus will be on spent fuel and defense high-level waste that will be disposed of in a geologic repository.



*Includes spacing between fuel assembly rods. DOE/Defense Program spent fuel to be reprocessed is not shown.

**DOE/Defense Program spent fuel to be reprocessed is not shown.

Directions: Using the information in the reading lesson and the pie charts above, answer the questions.

1. As of 1993, more than *(20%)* percent of our Nation's electricity was generated by nuclear powerplants.

2. What percentage of the total amount of radioactive waste is:
   a. low-level? *(58.84% + 28.29% = 87.13%)* b. high-level? *(0.04 + 7.60% = 7.64%)*
   c. spent fuel? *(0.22%)* d. transuranic? *(5.02%)*

3. What is the source of the greatest volume of high-level waste? *Defense* %? *(7.60%)*

4. What type of waste represents:
   a. the greatest amount of radioactivity? *(Spent fuel)* %? *(96.29%)*
   b. second greatest amount of radioactivity? *(Defense high-level waste)* %? *(3.55%)*

5. What two sources represent the least radioactivity?
   a. *(Transuranics)* %? *(0.01%)* b. *(Low-level commercial)* %? *(0.02%)*

6. a. Although spent fuel is *(0.22%)* of the accumulation of radioactive waste, it contains *(96.29%)* of the radioactivity.
   b. Low-level defense and commercial wastes represent *(87.13%)* of the volume of waste but only *(0.07%)* of the radioactivity.

7. What is the significance of the information in these pie charts?
   (Most radioactive waste is low-level and does not require disposal in a repository. A small percentage of the total volume of radioactive waste is high-level, transuranic, or spent fuel and requires permanent disposal in a repository. The small volume of spent fuel and defense high-level waste contains the greatest percentage of radioactivity.)

NUCLEAR WASTE: WHAT IS IT? WHERE IS IT?

A. In the blanks provided, write the number of the statement that best describes the terms that are listed. A response may be used only once. All responses will not be used.

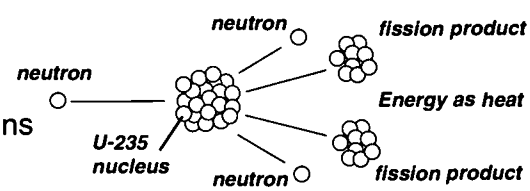
TERMS	ANSWERS
(4) A. Geologic Repository	1. byproduct from using radioactive material
(6) B. Spent Fuel	2. discarded protective clothing from "housekeeping" functions of commercial and university nuclear facilities
(7) C. Fuel Rods	3. depends on its origin, level of radioactivity, and potential hazard
(1) D. Nuclear Waste	4. deep underground facility
(2) E. Low-Level Waste	5. organization of States with purpose of providing for disposal of low-level waste from all members
(3) F. Classification of Waste	6. has been used in a nuclear reactor and doesn't contribute efficiently to the nuclear chain reaction
(5) G. Compact	7. hollow metal tubes containing nuclear powerplant fuel
	8. spent fuel and defense high-level waste that will be disposed of in a geologic repository

B. List the four categories of nuclear waste and give the source or sources for each type.

	Type	Sources	Planned Permanent Disposal Method
1.	*(High-Level)*	*(Spent fuel and defense high-level waste)*	*(Geologic repository)*
2.	*(Low-Level)*	*(Many commercial and industrial processes)*	*(Specially designed above-ground facilities or shallow land burial)*
3.	*(Transuranic)*	*(Manmade elements formed as a byproduct of operation of a nuclear reactor; most results from processing nuclear fuel as part of U. S. defense activities)*	*(Geologic repository)*
4.	*(Mill Tailings)*	*(Naturally radioactive rock and soil that are byproducts of mining and milling uranium)*	*(Covering with dirt)*

C. Arrange the following phrases in the correct order. Then draw a diagram that illustrates the sentence you have made.

causing the nucleus to split apart
a neutron
releasing energy, fission products, and more neutrons
strikes the nucleus of a uranium-235 atom



(A neutron strikes the nucleus of a uranium-235 atom and causes the nucleus to split apart, releasing energy, fission products, and more neutrons.)

D. Indicate whether each statement is true (T) or false (F) by writing the correct letter in the blank. If the statement is false, correct it to make it true.

(T) 1. The U.S. Department of Energy (DOE) is responsible for establishing a system for the disposal of high-level radioactive waste.

(T) 2. Mill tailings contain small amounts of radium that decay to radon, a radioactive gas.

(F) 3. Transuranics represent the most radioactive category of nuclear waste.

(F) 4. All radioactive waste must be handled by remote control from behind heavy shielding.

(F) 5. Nuclear fuel burns.

E. Complete each of the following sentences.

1. Nuclear waste requires special disposal because *(it is necessary to avoid possible health and environment hazards associated with radiation).*

2. The amended Nuclear Waste Policy Act directed the U.S. Department of Energy to perform site characterization on *(Yucca Mountain, Nevada)* as a candidate site for a geologic repository.

3. Some high-level waste may contain elements that decay very slowly and may remain radioactive for *(thousands)* of years.

4. In 1994, over 109 nuclear powerplants operating in 35 States generated more than *(20)* percent of the Nation's electricity.

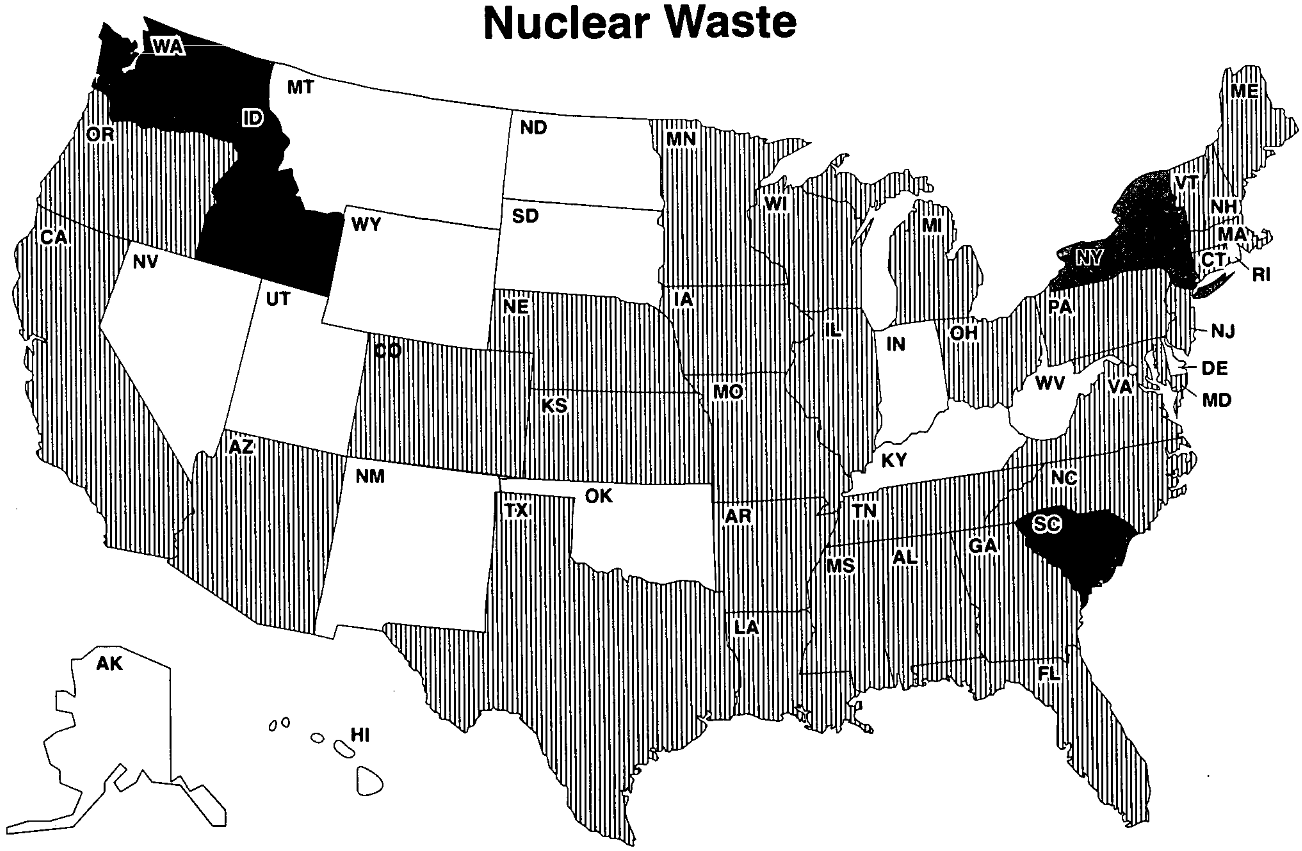
5. Approximately 8,000 to 9,000 metric tons of defense high-level waste are currently stored at three DOE sites: the *(Savannah River Plant, SC)*; the *(Hanford Reservation, WA)*; and the *(Idaho National Engineering Laboratory, ID)*.

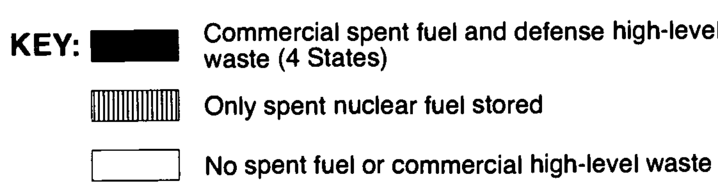
GEOGRAPHIC DISTRIBUTION OF COMMERCIAL SPENT FUEL AND COMMERCIAL AND DEFENSE HIGH-LEVEL NUCLEAR WASTE

In 1993, commercial spent fuel was stored in more than half of the States in the Nation. It is projected that by the year 2000, spent fuel inventories will nearly double. High-level waste from defense activities was stored in three States in 1991 and will continue to be stored there through the year 2000. In addition, a small amount of waste (1,729 cubic meters) that resulted from the reprocessing of commercial spent fuel was stored in West Valley, New York in 1991.

Fill in the map below to show the three groupings of States indicated by the map key. To make your groupings, use the information in the paragraph above and information in the reading titled *Nuclear Waste: What Is It? Where Is It?* The information in the reading is in the table titled *Spent Fuel Storage - 1993 and 2003* (Section 1.14) and the discussion of storage of high-level defense waste (Section 1.15). Read these sections again before beginning to work on the map.

Geographic Distribution of Commercial Spent Fuel and Commercial and Defense High-Level Nuclear Waste





GEOGRAPHIC DISTRIBUTION OF COMMERCIAL SPENT FUEL AND COMMERCIAL AND DEFENSE HIGH-LEVEL NUCLEAR WASTE

Directions: Using the completed map, the activity introduction, and information about *metric tons* of spent fuel for other high-level waste from the tables in the reading lesson, answer the questions below.

1. What is commercial waste? *(Waste generated by private enterprise, not government)*

   What is defense high-level radioactive waste? *(Waste that results from the reprocessing of specially designed and irradiated fuel to obtain materials for nuclear weapons.)*

2. In how many States was commercial spent fuel being stored in 1993? *(35)*

3. Was spent fuel stored in the State you live in during 1993? ________

4. If yes, how many metric tons? ________

5. If not, do you border a State that does? *(Yes) (Except for AK and HI)*

6. In which three States was defense high-level nuclear waste stored in 1991? (Use State abbreviations.) *(ID, SC, WA)*

7. In which State was commercial high-level waste (reprocessed spent fuel) other than spent fuel stored in 1993? *(NY)*

8. Which four States had the largest accumulations (in *metric tons*) of spent fuel in 1993? (Use State abbreviations.) *(IL, PA, NY, SC)*

   Which five States are projected to have the largest accumulations (in *metric tons*) by 2003? (Use State abbreviations.) *(IL, PA, NC, SC, NY)*

9. Commercial spent fuel and other high-level nuclear waste were not stored in 1993 and are not projected to be stored by the year 2003 in the following 15 States: (Use State abbreviations.)

   (AK, DE, HI, IN, KY, MT, ND, NM, NV, OK, RI, SD, UT, WY, WV)

10. In your opinion, what is the significance of the information in the map and in the tables?

    (Commercial spent fuel or defense high-level waste is present in 35 States and inventories of spent fuel are projected to increase greatly by 2000. The problem of safe permanent disposal is a national challenge.)

SUMMARY

1.18 Energy and Our Standard of Living

Today, most Americans enjoy a high standard of living. One reason for our high standard of living is that our businesses and industries can rely on adequate supplies of energy at prices they can afford to pay. The average citizen can also rely on adequate supplies of energy for personal and family needs at home. Electricity is an important part of this energy supply.

How is energy related to our high standard of living?

1.19 Nuclear Energy and Electricity

Every energy source used to produce electricity has both benefits and challenges. One challenge with using nuclear energy is that nuclear powerplants produce nuclear wastes. Nuclear wastes are radioactive. This means they require special handling, storage, and final disposal to protect the public and the environment from hazards associated with radiation. The accumulation of nuclear wastes is a national challenge.

How is electricity related to nuclear waste?

1.20 Categories of Nuclear Waste

There are four main categories of nuclear waste: (1) high-level waste, which includes spent fuel; (2) low-level waste; (3) transuranic waste; and (4) mill tailings. Each type will be disposed of in a way appropriate to its characteristics.

What are the types of nuclear waste?

High-Level Nuclear Waste: Spent Fuel

All spent nuclear fuel from commercial nuclear powerplants will be disposed of in a geologic repository for high-level waste. The U.S. currently has no plans for reprocessing high-level nuclear waste. The spent fuel rods will be sealed in special metal canisters for disposal.

What is spent fuel? How will it be disposed of?

Defense High-Level Waste

How is defense high-level waste disposed of?

High-level nuclear waste results from reprocessing spent fuel from defense reactors to recover uranium and/or plutonium. All high-level nuclear waste will be disposed of in a geologic repository. The waste is in liquid form after reprocessing. It will be made into a solid glass or ceramic form and will be sealed in metal canisters for permanent disposal. In 1985, President Reagan decided to dispose of high-level waste from defense activities in the same geologic repository that will be used for spent fuel from nuclear powerplants.

Low-Level Waste

What is low-level waste?

All radioactive waste other than spent fuel, high-level waste, and transuranic waste is considered to be low-level waste. Low-level nuclear waste is generated at commercial nuclear powerplants, hospitals, industrial and agricultural facilities, and academic institutions. Depending upon its activity, the low-level waste is now disposed of in various forms of shallow-land burial.

Who will be responsible for commercial low-level waste disposal?

Beginning in 1993, low-level waste generated from all activities, except Federal defense or research and development activities, became the responsibility of the State in which the waste is produced. Low-level waste will be disposed of in facilities developed by individual States or groups of States known as compacts.

Who will dispose of low-level waste from Federal activities?

Low-level waste from defense activities or research and development activities of the Federal Government will be disposed of at Federal sites, primarily where the waste is generated. It will not be disposed of at the commercial disposal sites States are responsible for.

Mill Tailings

How are they disposed of?

Mill tailings are generally disposed of where they are produced, at facilities where uranium ore is mined and milled. The Federal Government has responsibility for tailings at inactive milling facilities. Companies currently milling uranium must dispose of tailings according to State and Federal regulations.

Transuranic Waste

How will transuranic waste be disposed of?

Transuranic waste is mostly used clothing, rags, equipment, etc. It is similar to low-level waste but contains elements with very long half-lives. Although the total activity of transuranic wastes is no greater than certain low-level wastes, geologic disposal is considered necessary because transuranic waste loses radioactivity very slowly and remains hazardous for thousands of years.

Transuranic wastes result primarily from defense activities. Some transuranic waste is being stored in surface facilities, but current plans call for most of this waste and transuranic waste generated in the future to be ultimately placed in deep geologic storage. The U.S. Government plans to test disposal of transuranic waste at the Waste Isolation Pilot Plant (WIPP) facility in New Mexico. The type of rock at WIPP is bedded salt, which is composed of layers of salt left behind from ancient seas.

REGIONAL ELECTRICITY GENERATION

Part I

Much of the information and discussion in this introductory lesson gives students a "big picture" of electricity generation in the United States. If students can grasp the role of nuclear energy in providing the electricity used in the United States and the relationship between daily life and electricity, they should be better prepared to grapple with the issues surrounding nuclear waste and more interested in trying to understand the tradeoffs involved in utilizing any energy source, including nuclear energy.

Students may be interested in identifying the energy sources used to generate electricity in their State and/or region and in comparing sources used around the country. A discussion of the table *Net Generation by Energy Source, Census Division and State, 1994 (p. 126)* should introduce this activity. Students may be interested to know that a gigawatt is a billion watts. To help students visualize such a volume of energy, bring in a lamp with a 100 watt light bulb. Remove the shade and turn on the switch. Ask students to imagine that light if it were a million times brighter.

Draw the class attention to your State and encourage students to discuss the following:

1. Which source is used to generate most of the electricity in our State?

   (Answers will vary by State)

2. Why?

   (Encourage students to consider natural resources readily available in the State - number of waterways, coal, uranium, petrolem, natural gas, etc.)

3. How dependent is our State on nuclear energy?

   (It may be useful to have students consider their daily use of electricity in all forms and then ask them to think of reducing that use by cutting out nuclear energy as a source. If students live in a State where no utility uses nuclear energy to generate electricity, they may discuss 1) the possibility that the utilities in their State may purchase electricity generated by nuclear powerplants or 2) the possibility that they use products made using electricity from nuclear powerplants.)

4. What might be included in "other" sources?

   (The sources included in the data shown here are solar energy, waste to steam, wind energy, geothermal energy, and wood burning. Although tidal energy is not included in this table, students may suggest it as another possible energy resource.)

Because each group will be working with different census divisions, it will be difficult to work through a first example together. You may want to model this activity by calculating and drawing a pie chart illustrating the net generation by energy source for the entire United States on the board with your class. Use the following example *Making a Pie Chart – United States (p. 128)* as a guide.

Part II

Divide students into ten groups and assign each group a census division. Students should work together to complete the activity sheet entitled *Regional Electricity Generation* and to draw the pie charts (circle graphs) for their division. Numbers in bold-faced print represent totals for each energy source in each division. Students will need at least one protractor per group. A calculator will be helpful for finding percentages and converting to degrees.

Part III

It may be helpful to make a transparency from the answer sheets: *Net Generation by Energy Source and Census Division - Pie Charts*, so that each group may quickly evaluate their work. Allow students time to complete and check their graphs. Using the pie chart as a reference, discuss the following:

1. Which census division uses the greatest percentage of each source?

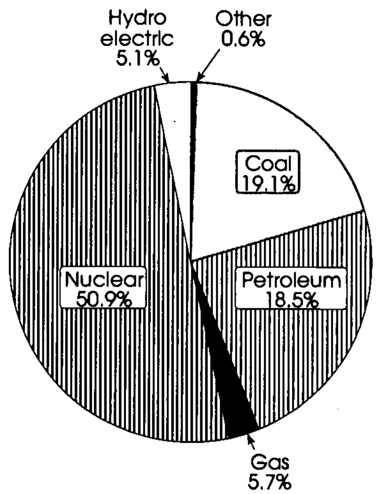
   Coal — East North Central; Petroleum — Pacific Non-Contiguous; Natural Gas — West South Central; Nuclear — New England; and Hydroelectric — Pacific Contiguous

2. Why?

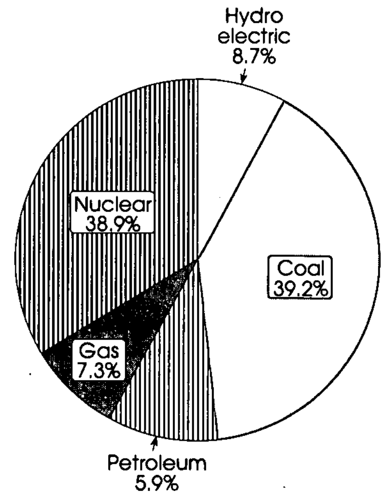
   (Again, you may want to discuss resources readily available in each division and even relate that to the geography of the region.)

Net Generation By Energy Source and Census Division
Pie Charts

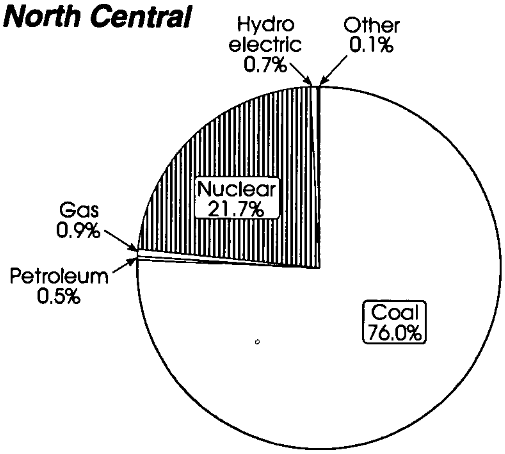
New England



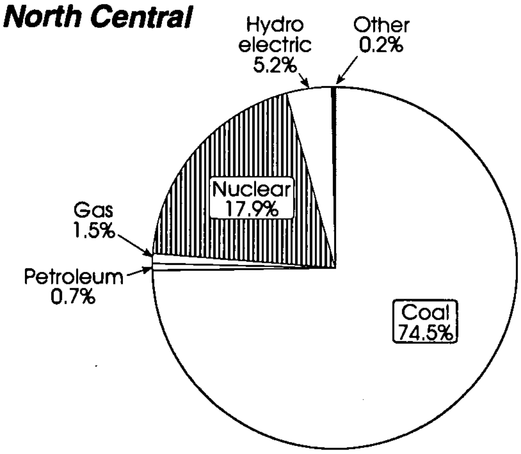
Mid-Atlantic



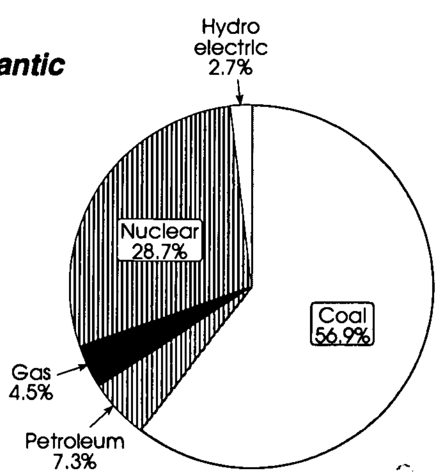
East North Central



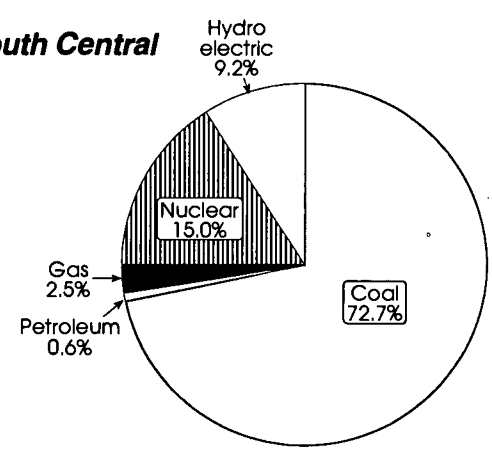
West North Central



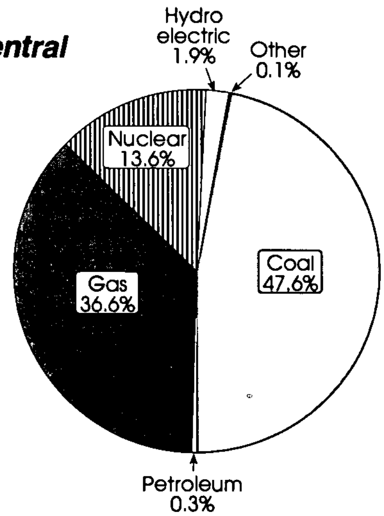
South Atlantic



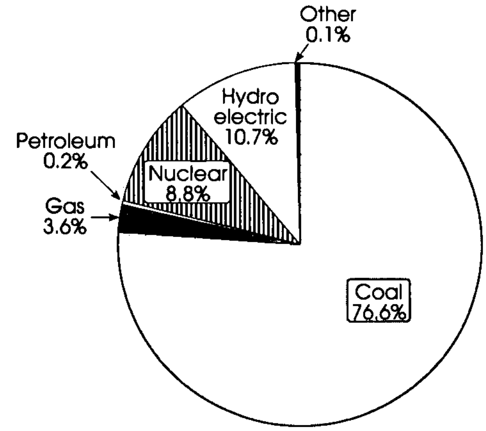
East South Central



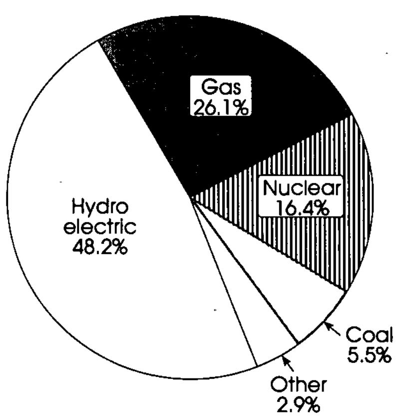
West South Central



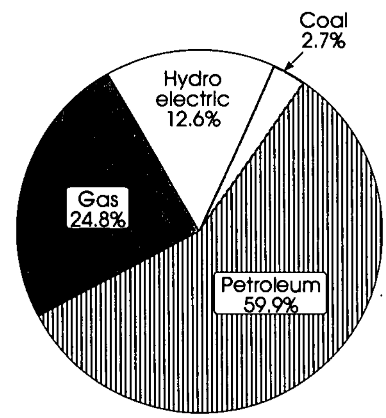
Mountain



Pacific Contiguous

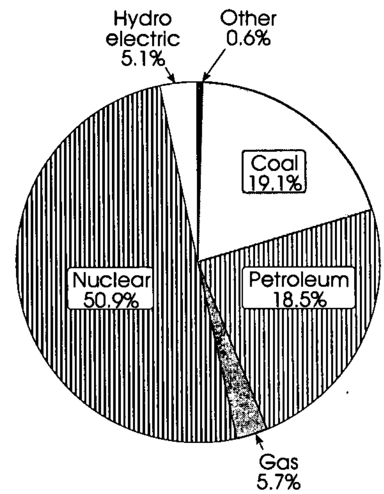


Pacific Non-Contiguous



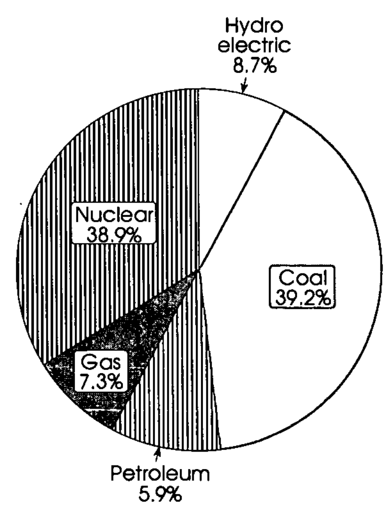
Census Division: New England

Source	Gigawatthours Produced	Percent	Degrees
Coal	15,495	19.1	69
Petroleum	15,009	18.5	67
Gas	4,624	5.7	21
Nuclear	41,206	50.9	183
Hydroelectric	4,125	5.1	18
Other	511	0.6	2
Total	**80,970**	**99.9**	**360**



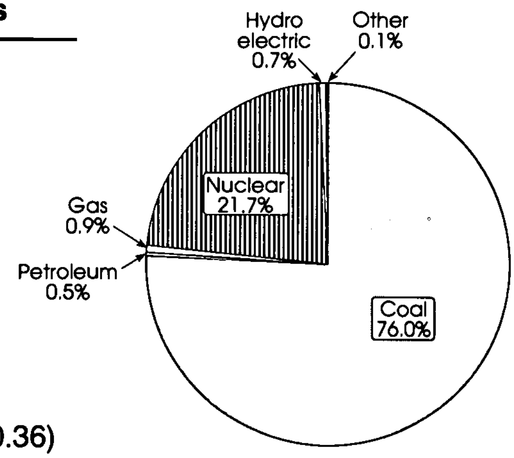
Census Division: Mid-Atlantic

Source	Gigawatthours Produced	Percent	Degrees
Coal	119,434	39.2	141
Petroleum	17,836	5.9	21
Gas	22,117	7.3	26
Nuclear	118,561	38.9	140
Hydroelectric	26,545	8.7	31
Other	11	0.00	0
Total	**304,504**	**100.00**	**359**



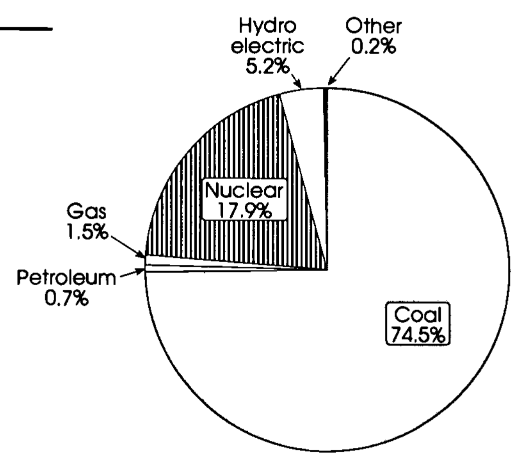
Census Division: East North Central

Source	Gigawatthours Produced	Percent	Degrees
Coal	383,432	76.0	274
Petroleum	2,617	0.5	2
Gas	4,547	0.9	3
Nuclear	109,267	21.7	78
Hydroelectric	3,280	0.7	3
Other	265	0.1	0 (0.36)
Total	**503,410**	**99.9**	**360**



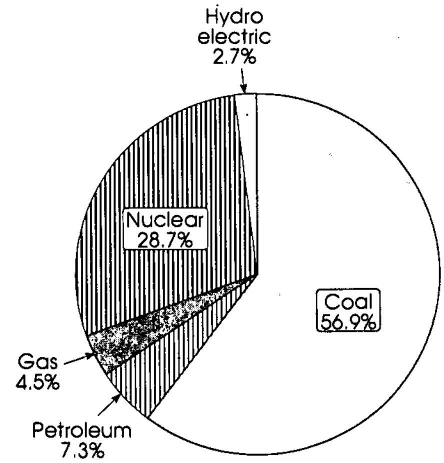
Census Division: West North Central

Source	Gigawatthours Produced	Percent	Degrees
Coal	171,911	74.5	268
Petroleum	1,573	0.7	3
Gas	3,439	1.5	5
Nuclear	41,212	17.9	64
Hydroelectric	12,025	5.2	19
Other	458	0.2	1
Total	**230,619**	**100.00**	**360**



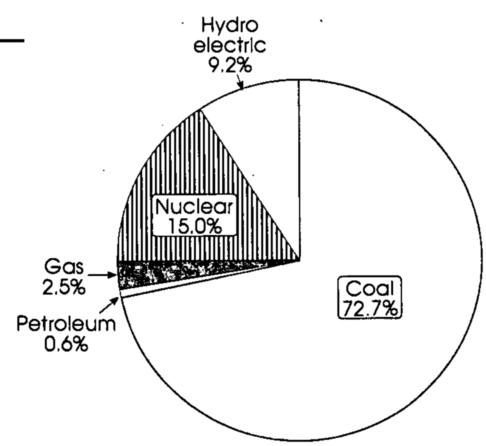
Census Division: South Atlantic

Source	Gigawatthours Produced	Percent	Degrees
Coal	335,071	56.9	205
Petroleum	42,719	7.3	26
Gas	26,458	4.5	16
Nuclear	169,081	28.7	103
Hydroelectric	15,746	2.7	10
Other	0	0	0
Total	**589,075**	**100.10**	**360**



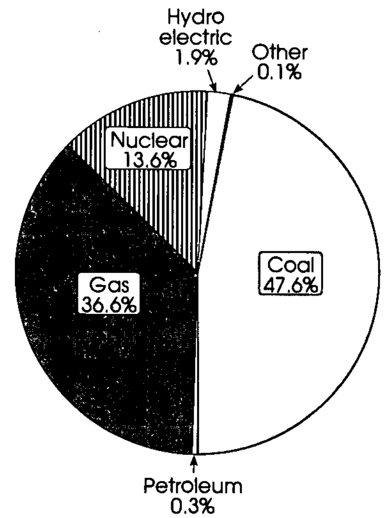
Census Division: East South Central

Source	Gigawatthours Produced	Percent	Degrees
Coal	203,689	72.7	262
Petroleum	1,676	0.6	2
Gas	7,111	2.5	9
Nuclear	42,027	15.0	54
Hydroelectric	25,841	9.2	33
Other	0	0	0
Total	**280,344**	**100.00**	**360**



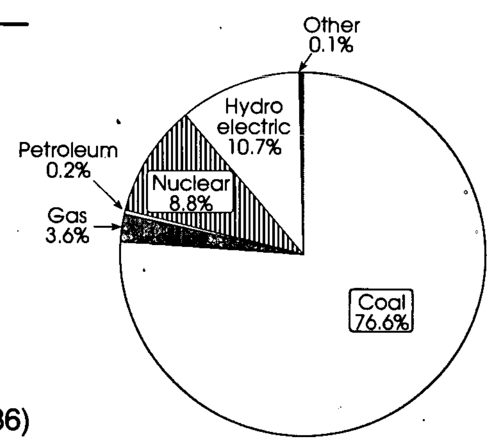
Census Division: West South Central

Source	Gigawatthours Produced	Percent	Degrees
Coal	189,967	47.6	171
Petroleum	1,097	0.3	1
Gas	145,998	36.6	132
Nuclear	54,347	13.6	49
Hydroelectric	7,457	1.9	7
Other	303	0.1	0 (0.36)
Total	**399,169**	**100.01**	**360**



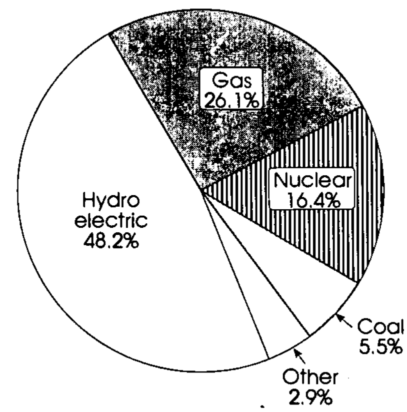
Census Division: Mountain

Source	Gigawatthours Produced	Percent	Degrees
Coal	202,183	76.6	276
Petroleum	423	0.2	1
Gas	9,563	3.6	13
Nuclear	23,171	8.8	32
Hydroelectric	28,302	10.7	39
Other	237	0.1	0 (0.36)
Total	**263,879**	**99.9**	**361**



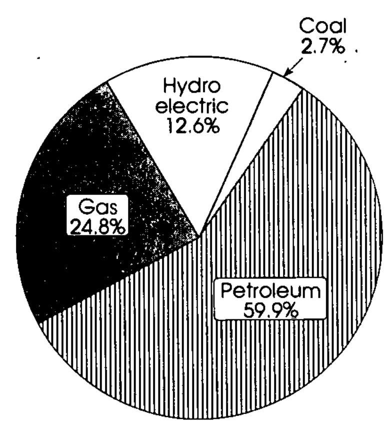
Census Division: Pacific Contiguous

Source	Gigawatthours Produced	Percent	Degrees
Coal	13,614	5.5	20
Petroleum	1,874	0.8	3
Gas	64,492	26.2	94
Nuclear	40,492	16.4	59
Hydroelectric	118,931	48.2	174
Other	7,163	2.9	10
Total	**246,566**	**100.00**	**360**



Census Division: Pacific Non-Contiguous

Source	Gigawatthours Produced	Percent	Degrees
Coal	295	2.7	10
Petroleum	6,477	59.9	216
Gas	2,681	24.8	89
Nuclear	0	0.00	0
Hydroelectric	1,364	12.6	45
Other	0	0	0
Total	**10,817**	**100.00**	**360**



INVENTORIES OF SPENT FUEL (Map Activity)

Purpose:

This lesson will enable students to determine which States currently have inventories of spent fuel. Additionally, a spatial perspective will be created that will accentuate the extent of the accumulation of spent fuel in the United States.

Concepts:

1. A national challenge exists because there is an accumulation of spent fuel.
2. Spent fuel is currently stored in 35 States.

Duration of Lesson:

Two 50-minute class periods

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. construct a choropleth map showing geographic distribution of inventories of spent fuel by volume and
2. analyze the patterns of distribution of spent fuel in the United States.

Skills:

Analyzing, critical thinking, data transferring, developing a frequency diagram, discussing, grouping, labeling, mapping, sorting

Vocabulary:

Choropleth map, cubic meter, frequency diagram, geographic distribution, inventory, spatial, thematic map

Materials:

Activity sheets
Inventories of Spent Fuel
Spent Fuel Inventories Number Line
1993 Inventories of Spent Fuel by State (blank U.S. map)

U.S. Map or Atlas (Optional for State abbreviations)
Colored pencils (Optional)

Suggested procedure:

A thematic map is about a single topic, such as inventories of spent fuel. Thematic maps with shaded or colored areas are choropleth maps. Their shading or coloring enables map readers to see patterns quickly, and for this reason, shading or coloring is progressively darker as data values increase.

The spent fuel inventory data can be visualized in two ways: 1) arranging data on the provided number line (also called a frequency diagram) and 2) filling in the map according to the volume ranges specified by the legend. In this lesson students will fill in the number line and the choropleth map for inventories of spent fuel using data taken from the table entitled *Spent Nuclear Fuel*, which appears on the enrichment activity sheet entitled *Spent Fuel Inventories Number Line*. Have the students fill in the number line first. The number line can be used to explain how the map legend was developed, or as an easy way to retrieve data when coloring the map.

An answer map is included in this enrichment activity.

1. Assign the enrichment activity entitled *Inventories of Spent Fuel*. The activity can be either an individual or group activity. To complete the activity, students will need copies of *Spent Fuel Inventories Number Line* and *1993 Inventories of Spent Fuel by State* (a blank U.S. map).

2. You may wish to begin by discussing the activity introduction, which describes thematic and choropleth maps and identifies for students the two ways they will view the data in this assignment: arranging data into prescribed categories on the number line and filling in a map according to the given legend.

3. Have students fill in the number line. Depending on the students, you may want to discuss where the number breaks could fall in order to have a nicely distributed map. Show them or tell them where to put the arrow marks so as to agree with the map.

Students should be able to complete the activity by following the directions on the activity sheet. Students should understand that the categories do not have to represent equal numbers on the number line or equal numbers of States. The goal is to establish categories that will show map readers a pattern.

The following questions may be helpful in discussing why the categories were developed as they were.

a) The States with spent fuel storage were divided into five categories. If only two categories were selected, what would the map show?

   (Probably, only the States that have spent fuel and the ones that do not. With only two categories, a range cannot be shown.)

b) What additional information will the map reader gain from the map showing five categories of spent fuel inventories?

   (The map reader will picture the range of spent fuel inventories.)

c) How should States with no stored spent fuel be shown on the map?

(There should be a sixth category in the legend for zero – those States with no inventory of spent fuel.)

d) On the number line, which categories have four or more States listed?

(1-300, 301-900, 901-1,500)

e) Which State has almost double the spent fuel of its closest counterpart?

(Illinois)

4. Selecting symbols or colors:

   One purpose of a choropleth map is to enable the map reader to see patterns quickly. Symbols or colors selected should reinforce visually the range of data values, with darker symbols or colors representing greater values. Some groups, or individuals, may need some help in thinking of symbols or in establishing a range of colors.

5. Have students label States and fill in the key and map with the colors or symbols they chose. Remind them that they can look off the number line they made or the table in section 1.14 Spent Fuel Storage.

6. The discussion questions below may be used to analyze patterns of distribution of spent fuel in the United States.

   a. In how many States was spent fuel being stored in 1993? *(35)*
   What percent of the States? *(70%)*

   In what region of the United States is spent fuel storage concentrated?

   (East of the Mississippi River)

   b. How many States had no spent fuel stored in 1993? *(15)*
   What percent of the States? *(30%)*

   In what region of the United States are most of these States located?

   (West of the Mississippi River)

   c. Are there clusters of States with high inventories of spent fuel?

   (A cluster of southeastern States and a cluster of middle Atlantic States have higher inventories of spent fuel.)

d. As you look at the map, do you see any relationship between population and inventories of spent fuel?

(The concentration of spent fuel is in the Eastern States where the greatest concentration of U.S. population is located.)

Is this what you would expect? Why or why not?

(Spent fuel is linked to use of electricity from nuclear powerplants. Where there are more people, there is generally more use of electricity so this is not unexpected.)

e. As you look at the map, do you see any relationship between States with inventories of spent fuel and States that are known for industrial output as opposed to ranching, mining, etc.?

(Most students will see that the greatest concentration of spent fuel is in the States east of the Mississippi and identify this region as being more industrial than the western States that have no spent fuel.)

Is this what you would expect? Why or why not?

(Spent fuel is linked to use of electricity from nuclear powerplants. Because industry generally requires electricity, this is not unexpected.)

f. The goal of an electric utility company is to provide least-cost and reliable supplies of electricity to customers. What factors do you think a utility considers when deciding what type of powerplant to build?

(A variety of factors influence the selection of technology and fuel, including the cost associated with construction, borrowing the money to finance building, etc. (i.e., capital costs); operation and maintenance costs; environmental restrictions on the technology and use of the fuel; regulations affecting fuel use; cost and availability of fuel; availability of capacity associated with the type of fuel.)

g. As you look at the map, do you see any link between State or regional natural resources related to generating electricity and the presence of spent fuel in States?

(The energy source used to generate electricity in any State or region is determined at least in part by the natural resources of the State or geographic region. For example, east of the Mississippi, only five States do not have an inventory of spent fuel. Two of those are Kentucky and West Virginia, which are both coal-producing States. In some western States, where rivers were available to build dams, hydropower produces a high percentage of electricity.)

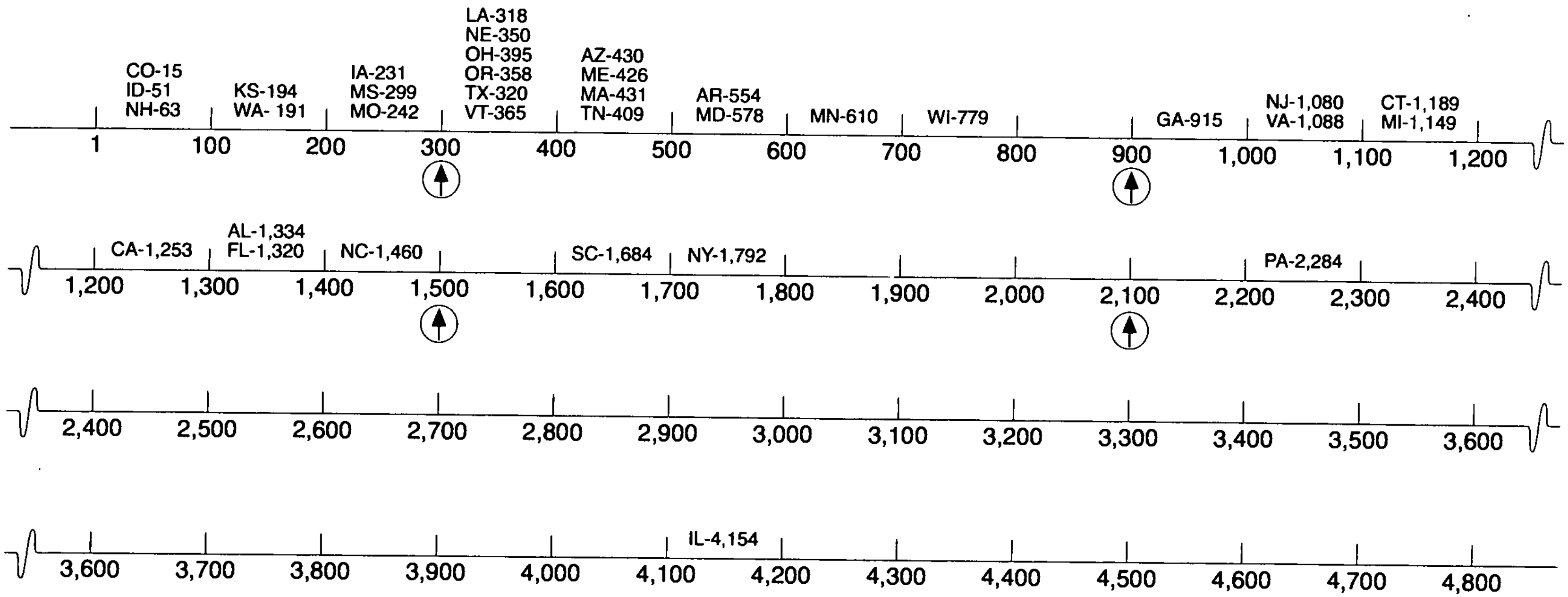
h. Do the factors of population, industry, and natural resources apply to the presence or absence of spent fuel in the State you live in? The region you live in?

(Answers will vary.)

Teacher Evaluation of Learner Performance:

Completion of the number line, activity map, and participation in discussion will indicate comprehension.

SPENT FUEL INVENTORIES NUMBER LINE



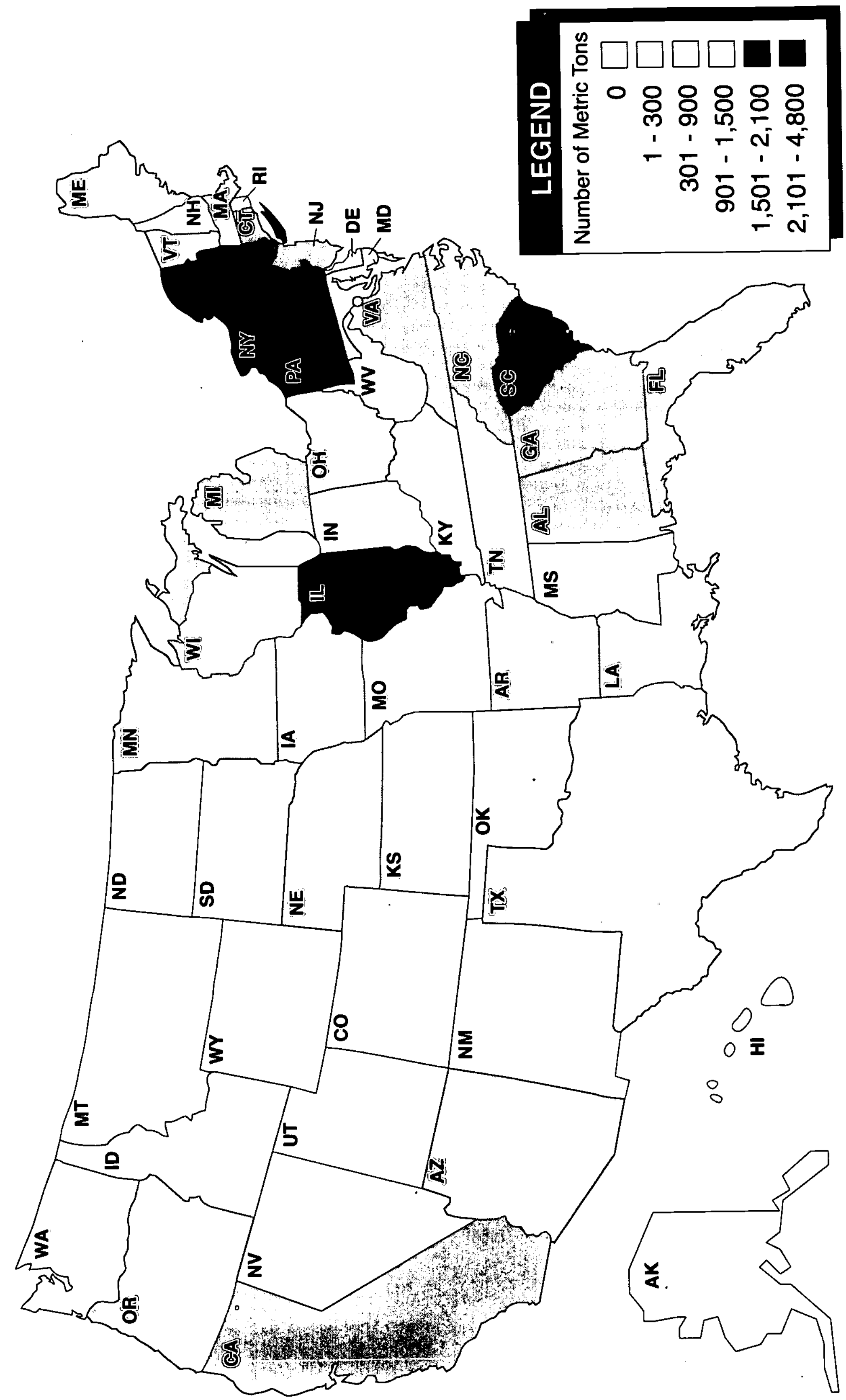
Symbol indicates number breaks for map legend

Symbol indicates that the number line is a segment of the range in values.

SPENT NUCLEAR FUEL

State	Spent Fuel 1993 (Metric Tons)	State	Spent Fuel 1993 (Metric Tons)	State	Spent Fuel 1993 (Metric Tons)	State	Spent Fuel 1993 (Metric Tons)
Alabama	1,334	Illinois	4,154	Mississippi	299	Pennsylvania	2,284
Arizona	430	Iowa	231	Missouri	242	South Carolina	1,684
Arkansas	554	Kansas	194	Nebraska	350	Tennessee	409
California	1,253	Louisiana	318	New Hampshire	63	Texas	320
Colorado	15	Maine	426	New Jersey	1,080	Vermont	365
Connecticut	1,189	Maryland	578	New York	1,792	Virginia	1,088
Florida	1,320	Massachusetts	431	North Carolina	1,460	Washington	191
Georgia	915	Michigan	1,149	Ohio	395	Wisconsin	779
Idaho	51	Minnesota	610	Oregon	358		

1993 INVENTORIES OF SPENT FUEL BY STATE
(In Metric Tons)



WORLDWIDE NUCLEAR WASTE MANAGEMENT

Purpose:

This lesson will help students understand how the United States and a representative sampling of other countries plan to dispose of their high-level nuclear waste. The number of nuclear powerplants, sites, and agencies involved in producing and managing nuclear waste are described. Special attention is focused on how the U.S. and these other countries plan to provide safe, permanent disposal of spent fuel and other high-level waste.

Concepts:

1. An international problem exists because there is an accumulation of nuclear waste.
2. Classification of nuclear waste depends on its source and the types and levels of radiation it emits.
3. Each country must plan to provide safe, permanent disposal of high-level nuclear waste.

Duration of Lesson:

One 50-minute class period

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. complete a matrix showing the number of powerplants, sites, and methods of storage for 12 countries;
2. state how each type of waste is or will be disposed;
3. provide short answers to discussion questions; and
4. discuss where spent fuel and/or high-level nuclear waste is currently stored in the countries mentioned in the videotape.

Skills:

Analyzing, charting, describing, discussing, drawing conclusions, evaluating, interpreting charts, synthesizing, writing

Vocabulary:

Geographic, high-level waste, nuclear reactor, radioactive, radioactivity, repository, reprocess, spent fuel

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Materials:

Reading Lesson
Nuclear Waste: What Is It? Where Is It?, p. SR-9

Activity Sheet
Worldwide Nuclear Waste Management, p. 135

Videotape
Worldwide Nuclear Waste Management, 20 minutes **(available free of charge by calling the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720)**

Background Note
International Nuclear Waste Disposal, p. 55

Suggested procedure:

1. Review the reading lesson entitled *Nuclear Waste: What Is It? Where Is It?*, if necessary.
2. Discuss the various types/categories of nuclear waste and on what classification of waste depends.
3. Make sure that students understand that most radioactive waste is low-level and does not require disposal in a repository. A small percentage of the total volume of radioactive waste is high-level, transuranic, or spent fuel and requires permanent disposal in a repository. The small volume of spent fuel and defense high-level waste contains the greatest percentage of radioactivity.
4. Have students look over the matrix activity. Explain that students should listen carefully so they can fill in all the spaces on the matrix. Make sure that they are familiar with the matrix before starting the videotape. Warn them that the videotape covers much information in a short time, so they should pay close attention.
5. View the videotape *Worldwide Nuclear Waste Management.*
6. Watch the videotape again, if necessary.
7. After students have finished filling in their matrices, have them answer the discussion questions.
8. Discuss the findings and any trends that students have noticed during their analyses.

Teacher Evaluation of Learner Performance:

Student participation in class discussion and completion of activity sheet will indicate understanding.

WORLDWIDE NUCLEAR WASTE MANAGEMENT

Fill in the matrix below while watching the videotape *Worldwide Nuclear Waste Management*. The matrix will give you the data needed to complete the discussion questions.

Country	Number of Powerplants	Number of Sites	Percent of Electricity Derived from Nuclear Power	Reprocess (Yes/No/NA*)	Year Repository is to Open or Be Sited
Belgium	7	2	60	Yes	2020
Canada	19	5	15	No	2015
Finland	4	2	35	No	2000
France	56	20	75	Yes	Early 2000's
Germany	22	17	33	Yes	2000
Japan	40	15	26	Yes	NA
The Netherlands	2	2	5	Yes	Near Future
Spain	9	7	38	Yes (for 1 plant)	Next Decade
Sweden	12	4	46	No	2020
Switzerland	5	4	43	NA	2020
United Kingdom	37	14	20	Yes	2005
United States	more than 100	33 States	21	No	2010

*NA = Information not available

NOTE: Since 1992, nuclear waste management programs have also been considered in Argentina, India, and Italy.

Discussion Questions

1. What is the total number of nuclear powerplants for the 11 countries other than the U.S.?

   (213)

2. Which country receives the highest percentage of electricity from nuclear power? *(France)*

   the lowest percentage? *(The Netherlands)*

3. What is the average percentage of electricity from nuclear power for these 12 countries?

   (34.75%)

4. Which country has the most nuclear powerplants? *(U.S.)* the least? *(The Netherlands)*

5. Does the country with the most nuclear powerplants also have the highest percentage of nuclear power? *(No)*

6. If not, why would a country with fewer nuclear powerplants have a higher percentage of electricity derived from nuclear power? Explain.

   (A country with fewer nuclear powerplants may have a smaller population and less industry to use the energy. Therefore, fewer powerplants can provide a greater percentage of the electricity.)

7. How many countries reprocess their fuel? *(7)*

8. What is the common goal for these and all other countries who operate nuclear powerplants?

   (To provide for the safe, permanent disposal of nuclear waste.)

9. In what kind of facility do these countries plan to dispose of high-level nuclear waste?

   (A deep underground geologic repository.)

10. When should siting or operation of these storage facilities begin for most of these countries?

    (In the early 21st century.)

INTERNATIONAL NUCLEAR WASTE DISPOSAL

Most nations with waste management programs currently either reprocess spent fuel or store it at reactor sites. Future plans for permanent disposal differ among nations; however, many nations and international agencies have expressed a consensus that disposal in geologic repositories is the long-term solution.

Plans for Geological Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste

Country	Waste Form to be Accepted by Repository	Possible Repository Host Rock
Argentina	HLW glass	Crystalline
Belgium	Spent fuel or HLW glass	Boom Clay
Canada	Spent fuel	Crystalline
Finland	Spent fuel	Crystalline
France	HLW glass	Clay or granite
Germany (FRG)	Spent fuel or HLW glass	Salt
India	HLW glass	Granite, basalt, or amphibolite
Italy	HLW glass	Clay or salt
Japan	HLW glass	Tuff, crystalline, or sedimentary rock
Netherlands	Spent fuel and HLW glass	Salt or clay
Spain	Spent fuel	Crystalline, salt, or clay
Sweden	Spent fuel	Crystalline
Switzerland	HLW glass	Crystalline, or sedimentary rock
United Kingdom	HLW glass	TBD
United States	Spent fuel and HLW glass	Tuff*

HLW = High-Level Wastes TBD = To be determined

Source: Nuclear Waste Technical Review Board, 1994.

**The United States is currently the only country involved in the process of site characterization. Various waste forms and host types are being evaluated.*

LOW-LEVEL WASTE (MAP ACTIVITY)

Purpose:

This lesson will describe current and future disposal of low-level nuclear waste. Plans of individual States for compliance with the provisions of the amended Low-Level Radioactive Waste Policy Act of 1980 will be presented. Sources of low-level waste and amounts disposed of will be examined at a national, State, and regional compact level. Students will also investigate relationships between volumes of waste and levels of radioactivity.

Concepts:

1. A national problem exists because there is an accumulation of nuclear waste.
2. The amended Low-Level Radioactive Waste Policy Act requires that the disposal of low-level nuclear waste be conducted by individual States or regional groupings of States known as compacts.

Duration of the Lesson:

Two 50-minute class periods

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. list the two Federally licensed sites where commercial low-level waste is currently disposed of;
2. discuss provisions of the amended Low-Level Waste Policy Act of 1980 regarding each State's responsibilities for low-level waste disposal;
3. explain how the State he/she lives in will dispose of low-level waste after 1993;
4. construct a choropleth map showing amounts of low-level waste disposed of in 1993 at Federally licensed sites by State;
5. analyze patterns of disposal of low-level nuclear waste in the United States in 1993; and
6. analyze the relationship between volume and level of radioactivity of low-level waste.

Skills:

Analyzing, critical thinking, data transferring, discussing, evaluating, explaining, graphing, grouping, interpreting maps, labeling, listing, mapping, reading, sorting, synthesizing

Vocabulary:

Choropleth map, commercial, compact, cubic feet, Federally licensed sites, frequency diagram, geographic distribution, LLRWPA, Low-Level Radioactive Waste Policy Act of 1980, shallow land burial, spatial, thematic map, unaffiliated State

Materials:

Reading Lesson

Nuclear Waste: What Is It? Where Is It? (Optional), p. SR-9
Low-Level Waste, p. SR-11

Activity Sheets

Low-Level Waste Parts I and II, pp. 139-150
Low-Level Waste Compacts, December 1992, p. 143
Low-Level Waste Number Line, p. 145
Low-Level Waste Received at Disposal Sites - 1993 (blank U.S. map—If students use colors to indicate disposal by State, the same map can also be used to indicate compacts and unaffiliated States. If students use symbols to show disposal by States, they will need a second outline map for the compacts.), p. 147

Other

U.S. Map or Atlas (Optional)
Colored pencils (Optional but helpful in enabling students to put all information on one map)
Protractor
Calculator (Optional)

Background Notes

Low-Level Waste, p.63

Suggested procedure:

Student activities for this lesson are divided into two separate parts. In Part I, students use data provided to make a map of unaffiliated states and compacts formed for regional disposal of low-level waste; fill in a number line for state low-level waste volumes; and make a map of low-level waste inventories in the U.S. In Part II, students make circle graphs to show the percentages of low-level waste disposal from five sources.

Part I

A thematic map is about a single topic, such as inventories of spent fuel or disposal of low-level waste by State. Thematic maps with shaded or colored areas are choropleth maps. Their shading or coloring enables map readers to see patterns quickly, and for this reason, shading or coloring is progressively darker as data values increase.

The data on Low-Level waste received can be visualized in two ways: 1) arranging data on the provided number line (also called a frequency diagram) and 2) filling in the map according to the volume ranges specified by the legend. In this lesson, students will fill in the number line and the choropleth map about disposal of low-level nuclear waste using data taken from the table entitled *1993 Sources and Volumes of Low-Level Waste Received at Disposal Sites* on the activity sheets entitled *Low-Level Waste*. Have the students fill in the number line first. The number line can be used to explain how the map legend was developed, or as an easy way to retrieve data when coloring the map.

Assign the enrichment activity entitled *Low-Level Waste*. The activity can be either an individual or group activity. To complete the activity, students will need copies of the instructions, including the table of disposal by State entitled *1993 Volumes of Low-Level Waste Received at Disposal Sites*, the *Low-Level Waste Number Line*, and either one or two copies of the outline map. Note that most of Part I of this enrichment activity is very similar to the enrichment activity entitled *Spent Fuel Inventories*. (See Days 4 & 5.) However, this activity requires students to complete two additional steps. In Step 4 of Part I, they must convert data to units of thousands of cubic feet, and in Part II, they must make a pie chart (circle graph).

- If students did not complete the activity entitled *Spent Fuel Inventories*, you may wish to begin by discussing the activity introduction, which describes thematic and choropleth maps and identifies for students the two main steps they will need to perform in order to complete the assignment – arranging data in the established categories on the number line and filling in the map to show low-level waste volumes by State.

- Filling in the data table and number line:

  Students should be able to complete the activity by following the directions on the activity sheet. They may find it helpful to do one or two examples for the data table in Step 3 and then assign States to the correct space on the number line. After students have finished through Step 4 of the activity directions, you may wish to initiate a class discussion about how the data was organized and how it provides well-distributed categories of volume spans. It is important that students understand that the data can be grouped into categories in more than one way. Students should understand that the categories do not have to represent equal numbers on the number line nor equal numbers of States. What they are trying to do is see a pattern in the distribution of low-level waste.

  Begin with the basic concept of compacts and completing the map, which will visually show students these regional agreements. Then, have students list low-level waste compacts and assign symbols or colors for each compact in the legend on the worksheet. Once the legend is prepared, have them fill in the map with postal abbreviations for states and the colors or symbols they picked to identify compacts.

  When moving onto the number line and inventory volume map parts of this activity, the following questions may be helpful in discussing the established categories. If students completed the activity entitled *Inventories of Spent Fuel*, some of these will be repetitive.

A. The states with spent fuel storage were divided into five categories. If only two categories were selected, what would the map show?

   (Probably, only the States that disposed of low-level waste in 1993 and the States that did not. With only two categories, a range cannot be shown.)

B. What additional information will the map reader gain from the map showing four categories?

   (The map reader will picture the range of low-level waste inventories.)

C. How many States disposed of no low-level waste in 1993 or disposed of less than 500 cubic feet? How should these States be shown on the map?

(Fifteen States either disposed of no low-level waste or less than 500 cubic feet of waste in 1993. They should be left blank on the map. Puerto Rico also disposed of no low-level waste in 1993 and should be left blank.)

D. On the number line, which categories have four or more States listed?

(0-10, 10-20, 30-40)

E. Which categories have only one State listed?

(40-50, 50-60, 60-70, 70-80, 80-90, 100-110)

F. Selecting symbols or colors:

Because one purpose of a choropleth map is to enable the map reader to see patterns quickly, symbols or colors selected should reinforce visually the range of data values, with darker symbols or colors representing greater data values. Some groups may need some help in thinking of symbols or in establishing a range of colors.

G. Students should fill in the legend with colors or symbols for the pre-established categories and fill in the map to show a pattern of low-level waste received by States.

H. When students and/or groups have completed the maps, discuss them. Ask as many students as possible to share with the class what they learned from the map.

The following questions may be helpful:

1. Ask students to explain why they think the State volumes were divided into these five categories.

   (Answers will vary)

2. Have students explain the significance of the symbols or colors they selected for use on their choropleth maps.

   (Answers will vary, but should include information such as darker colors or symbols represent greater data values.)

3. Ask students to describe to the class the overall significance of the maps they have constructed.

   (Answers will vary, but may include comment on the location of the three federally licensed sites where commercial low-level waste is currently disposed of, an indication of how much low-level waste is disposed of at federally licensed sites and where it comes from, and an analysis of patterns of disposal of low-level waste in the United States in 1993.)

Part II

A. Students are instructed to study and finish the partially complete pie chart for the enrichment activity *Low-Level Waste Disposal by State* before figuring the percentage of low-level waste disposed of by their home State. You may wish to assign a different State to each student and have students share and compare results.

B. Students should be able to complete Part II of this activity by following directions and filling in the tables on the activity sheet. A calculator will be helpful in finding the decimal fractions and converting percents to degrees. It may be helpful to do the first conversion as a group. For example, for the percentage of volumes of waste from academic:

12,172 ÷ 792,182 = 0.0154
Round 0.0154 to 0.015
Convert to percent = 1.5% (round to nearest half-percent)
Convert to degrees: 0.015 x 360° = 5.5°

C. When students have completed the pie charts, analyze the charts. The questions that follow may be helpful.

1. What percentage of low-level waste disposed of by your home State or the compact your State belongs to came from each category in 1993?

   (Answers will vary)

2. Of the five sources of low-level waste listed (academic, government, industrial, medical, and utility) which was the heaviest producer of low-level waste in your area? Does this information tell you anything in particular about your home State?

   (Answers will vary)

3. After completing the map and pie chart activities on low-level waste, can you conclude why the U.S. Congress felt it was necessary to pass the Low-Level Radioactive Waste Policy Act and amendments?

   (Answers will vary, but should include comment upon the necessity to provide for a national disposal system to manage low-level wastes and making disposal of commercially generated low-level radioactive waste a responsibility of each State and encouraging the States to form interstate compacts to manage and dispose of low-level waste on a regional basis.)

D. Have students write, in a few sentences, what they have learned from this lesson.

Teacher Evaluation of Learner Performance:

Completion and discussion of the number line, activity map(s), pie charts, and written assignment on what has been learned will indicate comprehension.

LOW-LEVEL WASTE

Every State produces Low-Level Waste. However, there are only two commercial low-level waste disposal sites currently in operation. They are in Barnwell, South Carolina and Hanford, Washington.

Industrial low-level waste sources include, among others, radiochemical and pharmaceutical companies and manufacturers of smoke detectors and luminous dials. In March 1981, the Nuclear Regulatory Commission (NRC) removed some of the restrictions on the disposal of radioactive biomedical waste. This was done to decrease the volumes of very low-level radioactive waste shipped to NRC-licensed commercial disposal facilities from hospitals, laboratories, medical schools, and other institutions. Representative characteristics of this institutional waste indicate three distinct waste "streams" which can be categorized as nonbioresearch and medical. Bioresearch waste results mainly from chemical tracers used in animal studies, and medical waste comes from medical diagnostic and therapeutic practices.

Three commercial low-level waste disposal sites in the eastern United States (Maxey Flats, Kentucky; Sheffield, Illinois; and West Valley, New York) have been closed to further use. The closure of these three commercial low-level waste disposal sites resulted in increasing volumes of low-level waste being shipped to the two remaining operating sites in South Carolina and Washington. The increase prompted South Carolina to impose a cap on the volume of low-level waste that could be accepted at Barnwell. Eventually, a general concern developed that the responsibility for low-level waste disposal should not rest with so few States, and a coordinated national plan was needed.

The Low-Level Radioactive Waste Policy Act was passed in 1980, making each State responsible for its own low-level waste and encouraging formation of regional interstate compacts to deal with the disposal problem. The Act provided that any compact approved by Congress could restrict access to its low-level waste disposal facility and accept waste from only member States after January 1, 1986.

However, by 1984, it became evident that no new regional disposal facilities would be operating by the end of 1985. This gave rise to the Low-Level Radioactive Waste Policy Amendments Act, which continued to encourage interstate compact formation while requiring that non-sited (i.e., without an operating disposal site) States and compacts meet specific milestones leading to the operation of new regional facilities by January 1, 1993. As of 1994, these milestones had not been met by the affected States. Additionally, the Low-Level Radioactive Waste Policy Amendments Act established rates and limits of acceptance at the commercial disposal sites now in operation, as well as space allocations for utility wastes. The utilities are required to meet certain waste volume reductions during a 7-year transition period, which is provided for the opening of new low-level waste disposal sites under State compact arrangements. The full impact of the new law is being studied.

The States that comprise each compact and a list of unaffiliated States are given in this section for the enrichment activity entitled *Low-Level Waste Disposal by State.*

LOW-LEVEL WASTE

Low-level nuclear waste and high-level nuclear waste have different characteristics and, therefore, are disposed of differently. Historically, some quantity of low-level radioactive waste has been generated in every State from a variety of commercial sources, including academic, government, and industrial research; manufacturing processes; medical diagnosis and therapy; and electricity generation. Currently, these wastes are disposed of at Federally licensed sites in Barnwell, South Carolina and Hanford, Washington. A third site, Beatty, Nevada, closed at the end of 1992, but still contains waste.

To provide a national disposal system to manage low-level wastes, the U.S. Congress passed the Low-Level Radioactive Waste Policy Act and amendments. These laws make disposal of commercially generated low-level radioactive waste a responsibility of each State. States are encouraged to form interstate compacts to manage and dispose of low-level waste on a regional basis. The District of Columbia and Puerto Rico must also comply with provisions of this law. Nine compact regions have been formed and ratified by Congress; Texas, Maine, and Vermont have agreed at the State level to form a tenth compact with Texas as the host State. This agreement has not been approved by Congress at this date. New York and Massachusetts have declared themselves independent host States. As of March 1994, three States, as well as Washington, D.C. and Puerto Rico, remain unaffiliated. Unaffiliated States and States in compacts without an operating disposal site are required to meet specific milestones and deadlines leading to the operation of new regional disposal facilities by January 1, 1993. However, as of 1994, these milestones had not been met by the affected States.

1993 Sources and Volumes of Low-Level Waste Received at Disposal Sites (Cubic Feet)

	Academic	Government	Industry	Medicine	Utilities	Total
APPALACHIAN COMPACT	**1,503**	**6,326**	**3,760**	**117**	**48,811**	**60,517**
Delaware	4	1	489	7	0	501
Maryland	1,256	5,984	770	9	3,346	11,365
Pennsylvania	228	341	2,489	101	45,465	48,624
West Virginia	15	0	12	0	0	27
CENTRAL COMPACT	**647**	**251**	**205**	**39**	**23,598**	**24,740**
Arkansas	16	81	0	19	2,774	2,890
Kansas	118	4	160	16	2,428	2,726
Louisiana	331	1	30	1	6,798	7,161
Nebraska	165	5	0	0	11,598	11,768
Oklahoma	17	160	15	3	0	195
CENTRAL MIDWEST COMPACT	**420**	**22**	**2,891**	**214**	**63,436**	**66,983**
Illinois	218	2	2,645	214	63,436	66,515
Kentucky	202	20	246	0	0	468
MIDWEST COMPACT	**2,435**	**49**	**4,207**	**52**	**13,380**	**20,123**
Indiana	272	11	684	0	0	967
Iowa	525	0	8	0	1,474	2,007
Minnesota	655	2	282	0	4,118	5,057
Missouri	534	0	1,041	4	1,610	3,189
Ohio	400	31	2,175	48	4,023	6,677
Wisconsin	49	5	17	0	2,155	2,226

Table Continued

ENRICHMENT ACTIVITY *Science, Society, and America's Nuclear Waste*

	Academic	Government	Industry	Medicine	Utilities	Total
NORTHEAST COMPACT	**1,212**	**983**	**5,331**	**86**	**28,066**	**35,678**
Connnecticut	642	872	1,667	18	11,403	14,602
New Jersey	570	111	3,664	68	16,663	21,076
NORTHWEST COMPACT	**1,469**	**114,909**	**16,018**	**237**	**15,445**	**148,078**
Alaska	0	447	0	0	0	447
Hawaii	0	2,361	0	0	0	2,361
Idaho	300	23	2	0	0	325
Montana	0	0	0	0	0	0
Oregon	326	95,857	3,631	9	4	99,827
Utah	0	0	6,524	0	0	6,524
Washington §	843	16,221	5,861	228	15,441	38,594
Wyoming	0	0	0	0	0	0
ROCKY MOUNTAIN COMPACT	**326**	**0**	**12**	**0**	**38,333**	**38,671**
Colorado	326	0	0	0	38,333	38,659
Nevada	0	0	0	0	0	0
New Mexico	0	0	12	0	0	12
SOUTHEAST COMPACT	**2,727**	**51,699**	**120,851**	**1,340**	**99,275**	**275,892**
Alabama	10	214	187	21	12,645	13,077
Florida	184	143	813	74	11,312	12,526
Georgia	313	63	1,271	79	11,506	13,232
Mississippi	31	71	554	13	6,703	7,372
North Carolina	1,522	38	15,061	1,099	19,309	37,029
South Carolina §	243	8,513	8,315	5	18,401	35,477
Tennessee	320	6	82,364	44	1,924	84,658
Virginia	104	42,651	12,286	5	17,475	72,521
SOUTHWEST COMPACT	**115**	**10,511**	**3,560**	**419**	**13,366**	**27,971**
Arizona	0	5	0	0	8,148	8,153
California	115	10,493	3,560	419	5,218	19,805
North Dakota	0	4	0	0	0	4
South Dakota	0	9	0	0	0	9
UNAFFILIATED (Not members of any compact as of 1992)	**1,318**	**6,599**	**27,925**	**2,632**	**55,055**	**93,529**
Army Outside of U.S.	0	2,506	0	0	0	2,506
District of Columbia	0	0	0	0	0	0
Maine*	0	0	0	0	0	0
Massachusetts	200	3,384	4,819	131	16,431	24,965
Michigan	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0
New York	633	386	19,787	2,472	28,346	51,624
Puerto Rico	0	0	0	0	0	0
Rhode Island	0	0	0	0	0	0
Texas*	464	322	3,319	29	5,667	9,801
Vermont*	21	1	0	0	4,611	4,633
TOTAL	**12,172**	**191,349**	**184,760**	**5,136**	**398,765**	**792,182**

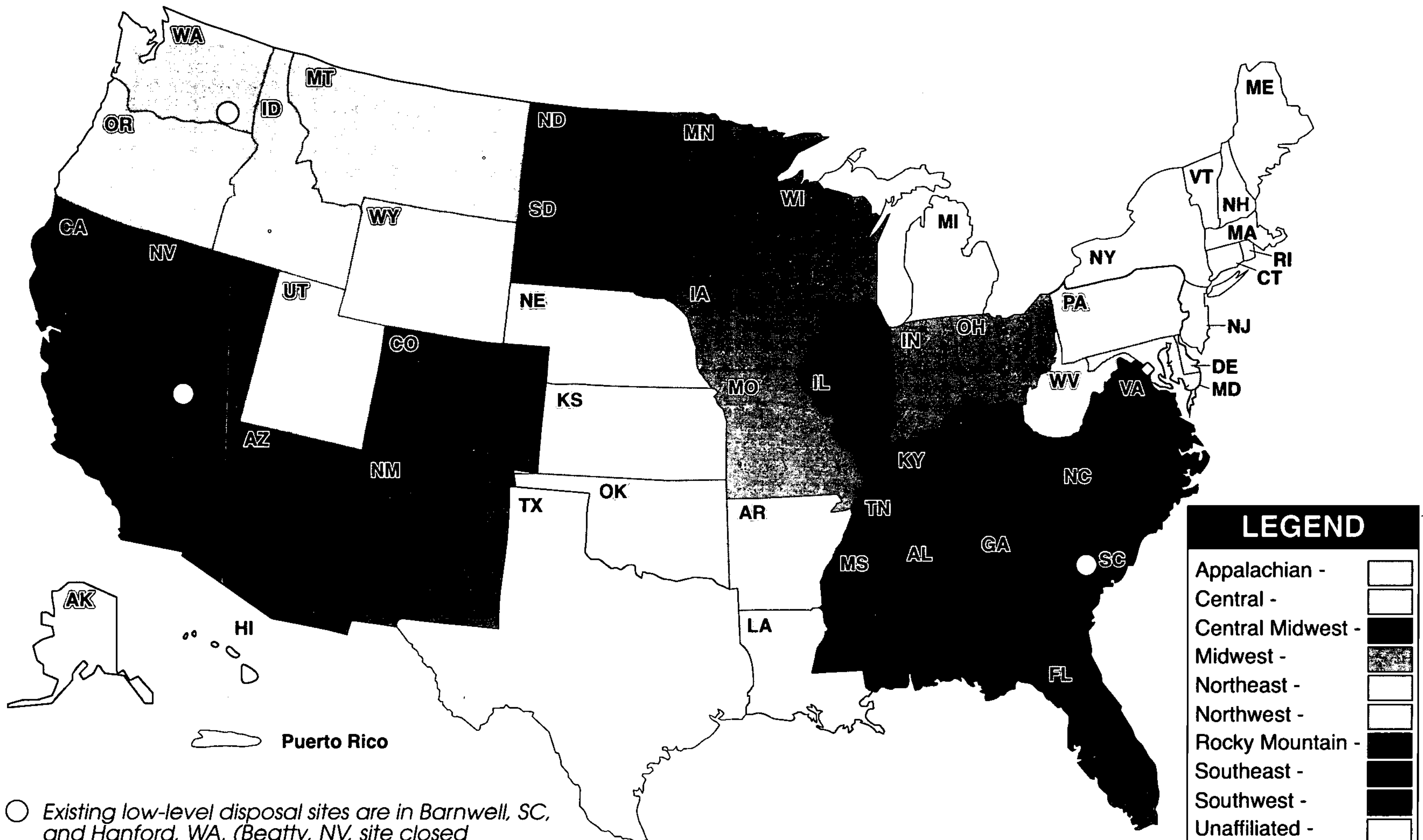
Note: Due to computer-generated rounding, totals may not add up exactly.

§ *Current location of disposal site. (Washington will host a site for the Northwest Compact and the Rocky Mountain Compact.)*

* *As of March 1994, Texas, Maine, and Vermont had agreed to form a tenth compact.*

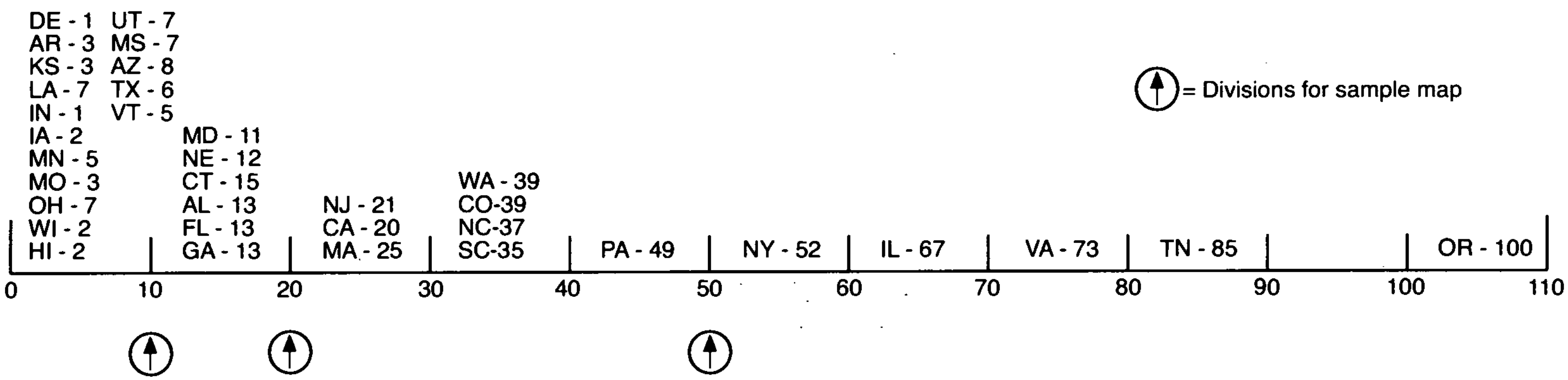
Source: The 1993 State-by-State Assessment of Low-Level Radioactive Wastes Received at Commercial Disposal Sites *(DOE/LLW-205), September 1994.*

LOW-LEVEL WASTE COMPACTS – DECEMBER 1993



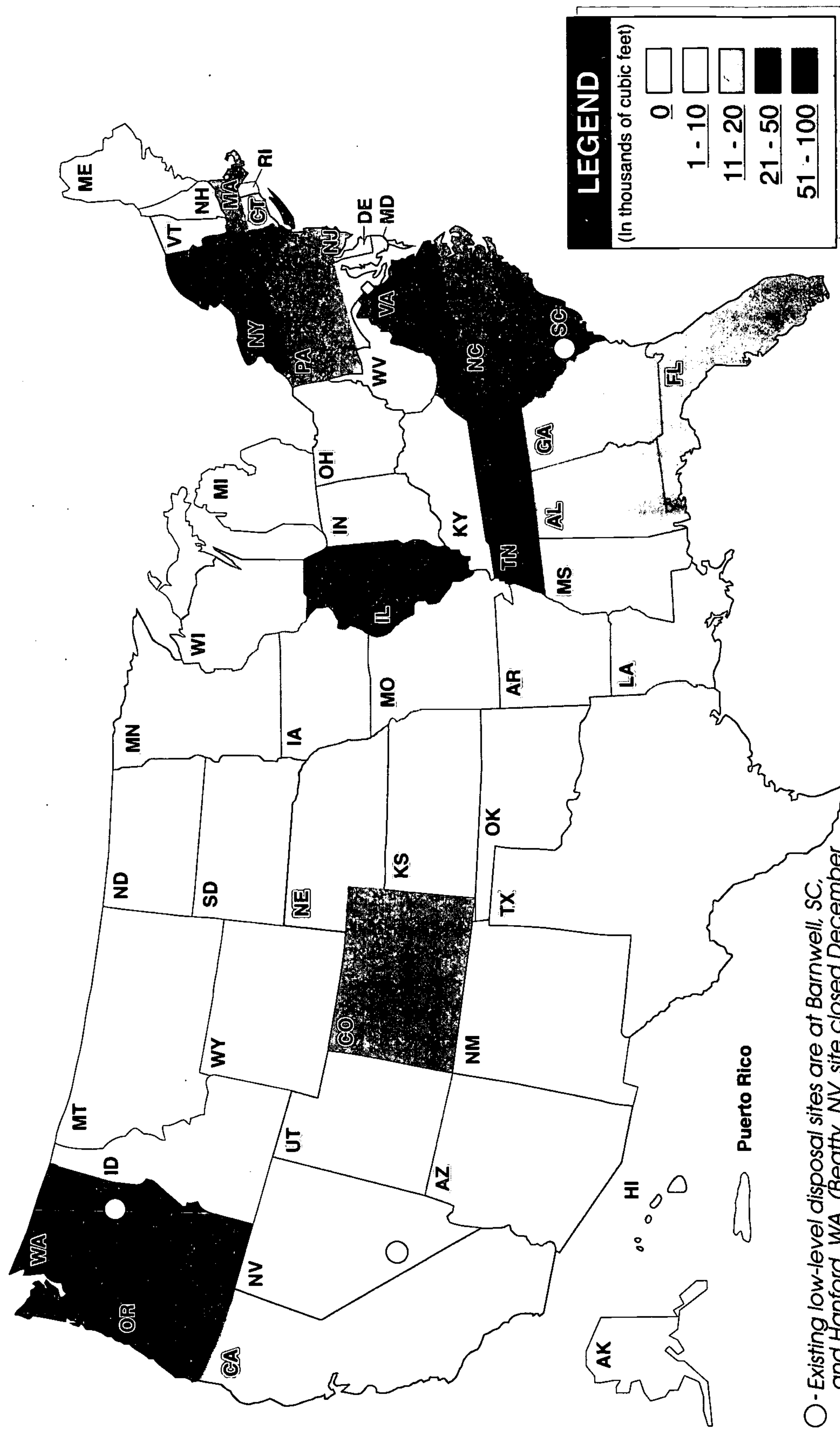
○ *Existing low-level disposal sites are in Barnwell, SC, and Hanford, WA. (Beatty, NV, site closed December 31, 1992.)*

LOW-LEVEL WASTE NUMBER LINE



DE	1,000	1	CT	15,000	15	NC	37,000	37
MD	11,000	11	NJ	21,000	21	SC	35,000	35
PA	49,000	49	AK	0	0	TN	85,000	85
WV	0	0	HI	2,000	2	VA	73,000	73
AR	3,000	3	ID	0	0	AZ	8,000	8
KS	3,000	3	MT	0	0	CA	20,000	20
LA	7,000	7	OR	100,000	100	ND	0	0
NE	12,000	12	UT	7,000	7	SD	0	0
OK	0	0	WA	39,000	39	DC	0	0
IL	67,000	67	WY	0	0	ME	0	0
KY	0	0	CO	39,000	39	MA	25,000	25
IN	1,000	1	NV	0	0	MI	0	0
IA	2,000	2	NM	0	0	NH	0	0
MN	5,000	5	AL	13,000	13	NY	52,000	52
MO	3,000	3	FL	13,000	13	PR	0	0
OH	7,000	7	GA	13,000	13	RI	0	0
WI	2,000	2	MS	7,000	7	TX	6,000	6
						VT	5,000	5

LOW-LEVEL WASTE RECEIVED AT DISPOSAL SITES – 1993



○ - Existing low-level disposal sites are at Barnwell, SC, and Hanford, WA. (Beatty, NV, site closed December 31, 1992.)

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LOW-LEVEL WASTE

Part II

Directions: Study and complete the table and pie chart below for low-level waste volumes disposed of in the U.S. as of 1993. Then construct a pie chart (circle graph) for low-level waste disposed of in your State and compare the two charts.

Percentages of low-level waste disposal in the United States

1. Complete the U.S. volume-to-degree conversions as practice before calculating percentages for your own State. For example, to get the academic source percentage of low-level waste for the pie chart below:

   12,172 ÷ 792,182 = 0.0154 (source/total)

   convert to percent = 1.5% (rounded to nearest half-percent)

   convert to degrees = 1.5% x 360° ÷ 100% = 5.5°

   (See the electricity production enrichment activity Making a Pie Chart - United States, *or ask your teacher for help in converting volumes to percents and degrees.)*

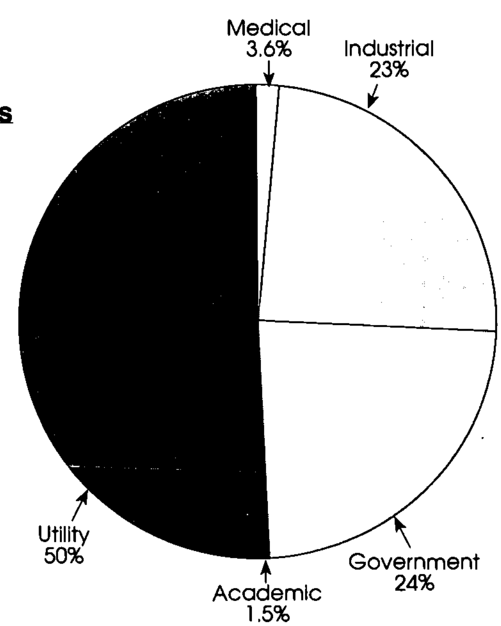
2. Fill in the missing percentages and degrees for the pie chart below.

Low-Level Waste Disposed of in the United States:

Source	Volume (Cubic Feet)	Decimal Fraction	Percent	Degrees
Academic	12,172	*0.0154*	*1.5%*	*5.4°*
Government	191,349	*0.2415*	*24%*	*86.4°*
Industrial	184,760	*0.2332*	*23%*	*82.8°*
Medical	5,136	*0.0065*	*1%*	*3.6°*
Utility	398,765	*0.5034*	*50%*	*80°*
Total	**792,182**		**99.5%***	**358.2°**

* Percentage total does not equal 100% due to rounding error.

VOLUME PERCENTAGE BY SOURCE



Percentages of low-level waste disposal in your State

Using the data given in the table entitled *1993 Sources and Volumes of Low-Level Waste Received at Disposal Sites*, make a pie chart to show the percentage of low-level waste disposed of by your home State in 1993 that came from each of the following sources: academic, government, industrial, medical, and electrical utilities. (If your home State did not dispose of low-level waste at one of the disposal sites in 1993, or if all the waste disposed of came from a single source, use the data for the compact your State belongs to or a neighboring State.)

1. Identify below the State for which calculations are being made and write in the volumes from the table entitled *1993 Sources and Volumes of Low-Level Waste Received at Disposal Sites.*

2. Calculate the fraction, expressed as a decimal, of the total for each source.

3. Round off and convert the decimal to percent.

4. Figure the number of degrees of a circle that will represent each percentage. (Remember that a circle has 360°. This means 50% will equal 180°, 25% will equal 90°, 10% will equal 36°, etc.)

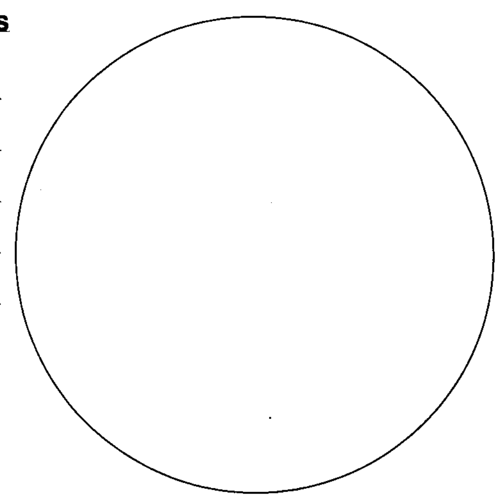
5. Using a protractor, use the circle below to make your pie chart.

6. Label the pie chart with the percentages and the categories they represent.

Low-Level Waste Disposed of in ______________________:

Source	Volume (Cubic Feet)	Decimal Fraction	Percent	Degrees
Academic	______	______	______	______
Government	______	______	______	______
Industrial	______	______	______	______
Medical	______	______	______	______
Utility	______	______	______	______
Total	______			

VOLUME PERCENTAGE BY SOURCE



(Answers will vary)

Glossary

atom - The smallest part of a chemical element that has all the chemical properties of that element.

atomic number - The number of protons in the nucleus of an atom. There is a separate atomic number for each element. The atomic number is used to identify atoms as gold, oxygen, or some other element.

byproduct - Something produced in addition to the principal or intended product; often waste.

ceramic pellets - The form of enriched uranium when prepared for nuclear reactor fuel use.

choropleth map - Map with shaded areas.

commercial - An adjective meaning of or engaged in commerce; commonly used to designate an operation or business as not owned by the government.

compact - Regional grouping of States to aid in the disposal of commercial low-level radioactive waste generated within member States.

controversial - Arousing disagreement.

cubic feet - The volume of a cube measuring 1 foot in each dimension.

cubic meter - The volume of a cube measuring 1 meter in each dimension.

defense high-level waste - Nuclear waste from the recovery of plutonium from uranium-metal reactor fuel for defense activities.

energy source - A means of producing the power to do work. Examples are fossil fuels (coal, oil, natural gas); geothermal, solar, nuclear, tidal energy.

Federally licensed sites - Three sites licensed for the storage of low-level waste. They are in Barnwell, SC, Beatty, NV, and Hanford, WA. *(Note: A former site in Nevada ceased operation on January 1, 1993.)*

fission - The splitting of a fissionable nucleus into two smaller, nearly equal, radioactive nuclei, accompanied by the emission of two or more neutrons and a significant amount of energy. Fission in a nuclear reactor is initiated by the fissionable nucleus absorbing a neutron.

fission products - The radioactive atoms produced by the splitting of uranium-235 in a nuclear reactor.

fossil fuel - A natural, burnable substance formed from ancient plant or animal matter. Examples are coal, oil, and natural gas.

frequency - The number of cycles per second of a wave.

frequency diagram - A number line on which data can be arranged based on the frequency of occurrence.

fuel assembly - A grouping of nuclear fuel rods that is put into or taken out of a nuclear reactor core as a unit. The reactor core is made up of a collection of fuel assemblies.

fuel pellets - Small cylindrical units of uranium dioxide about 1/4-inch in diameter and about 1/2-inch long that make up the fuel used in a pressurized-water reactor or a boiling-water reactor.

fuel rod - Twelve- to fourteen-feet-long metal tube that holds fuel pellets.

geographic - Relating to the surface of the Earth.

geographic distribution - Distribution of an item, such as spent fuel, based on geographic location.

gigawatthours - A million kilowatthours, a measure of electricity (giga = one billion).

high-level waste (HLW) - Also called high-level nuclear waste. (1) the highly radioactive waste resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste; (2) spent nuclear fuel itself; and (3) other highly radioactive material that the Nuclear Regulatory Commission determines by rule, or the DOE determines by order, to require permanent isolation.

inventory - A list of types and volumes of goods.

Low-Level Radioactive Waste Policy Act of 1980 (LLRWPA) - The U.S. law governing disposal of low-level radioactive waste; amended in 1985.

low-level waste - Materials such as laboratory wastes and protective clothing that contain only small amounts of radioactivity.

mapping - The process of making a flat representation of an area.

millirem - A unit of radiation exposure equal to one-thousandth of a rem.

mill tailings - The wastes from the recovery of uranium from its ore.

neutron - A sub-atomic particle that appears in the nucleus of all atoms except hydrogen. Neutrons have no electrical charge.

nuclear chain reaction - In a nuclear chain reaction, a fissionable nucleus absorbs a neutron and splits into two smaller, nearly equal nuclei, releasing additional neutrons. These in turn can be absorbed by other fissionable nuclei, releasing still more neutrons. This gives rise to a self-sustaining reaction.

nuclear energy - The energy released from the reactions of the nuclei of atoms.

nuclear powerplant - A powerplant that produces electricity from nuclear fission.

nuclear reactor - A device in which a fission chain reaction can be initiated, maintained, and controlled.

nuclear waste - Radioactive byproducts from any activity including energy and weapons production, as well as medical treatment and research.

nucleus - The central part of an atom that contains the protons and neutrons.

pie chart - A circular chart cut into segments illustrating relative magnitudes.

radiation - Energy that moves through space in the form of particles or electromagnetic waves.

radioactive - Of, caused by, or showing radioactivity.

radioactive waste - Waste resulting from work with radioactive materials.

radioactivity - The property possessed by some elements, such as uranium, of spontaneously emitting alpha or beta particles or gamma rays.

rem - A unit of exposure to ionizing radiation; an estimate of the health risk that exposure to ionizing radiation could have on human tissue.

repository - Any system licensed by the Nuclear Regulatory Commission that is designed for the permanent deep geologic disposal of high-level nuclear waste, including spent nuclear fuel and high-level radioactive waste from defense activities.

reprocessing - Extraction of uranium and plutonium from spent fuel for reuse.

shallow land burial - The current disposal process for low-level waste. Placing canisters of low-level waste in shallow trenches and covering with earth or shielding.

spatial - Relating to a position in space.

spent fuel - Fuel that has been used in a nuclear reactor and then withdrawn. Spent fuel is thermally hot and highly radioactive.

thematic map - A map providing information about a single topic.

transuranic - An element with an atomic number higher than the atomic number for uranium (92).

unaffiliated States - States not belonging to a compact for low-level waste disposal.

uranium - A naturally occurring radioactive element with the atomic number 92 and an atomic weight of approximately 238.

volume - A quantity as determined by the space occupied.

waste management - The handling and directing of the unwanted byproducts form a manufacturing process.

waste management system - The collection of facilities, equipment, personnel, and sites to be developed and deployed under control of the U.S. Department of Energy's Office of Civilian Radioactive Waste Management to accomplish the permanent disposal of spent fuel and high-level waste from defense activities.

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UNIT 1

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Science, Society, and America's Nuclear Waste

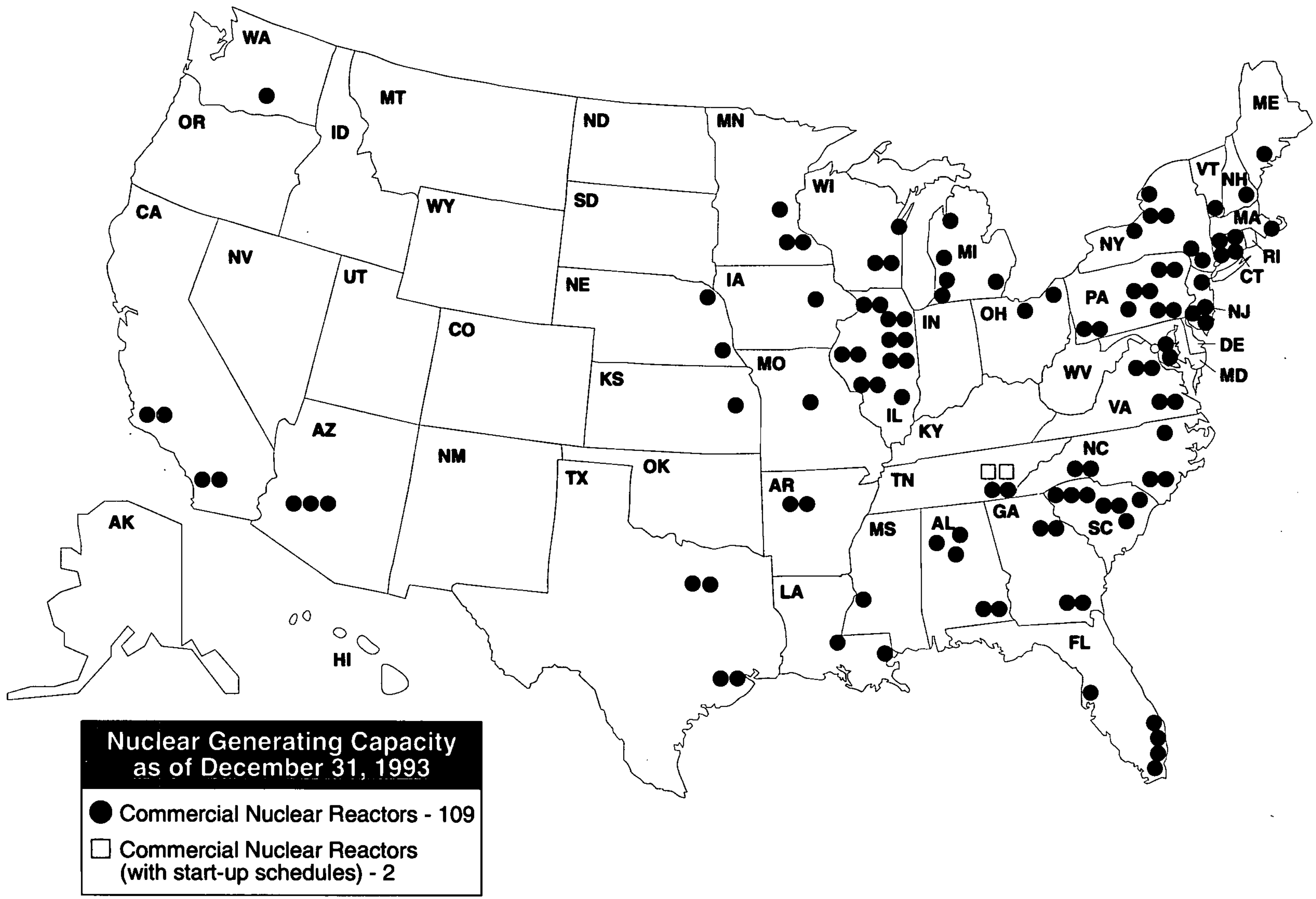
Transparency Masters & Student Activities

- Electricity from Nuclear Energy
- Radioactive Wastes: Volumes & Radioactivities
- Nuclear Waste: What Is It? Where Is It?
- Geographic Distribution of Spent Fuel and High-Level Nuclear Waste
- What Does Nuclear Waste Have to Do With Me?
- Regional Electricity Generation
- Inventories of Spent Fuel
- Spent Fuel Inventories Number Line
- 1993 Inventories of Spent Fuel by State
- Low-Level Waste
- Metric & U.S. Unit Conversions

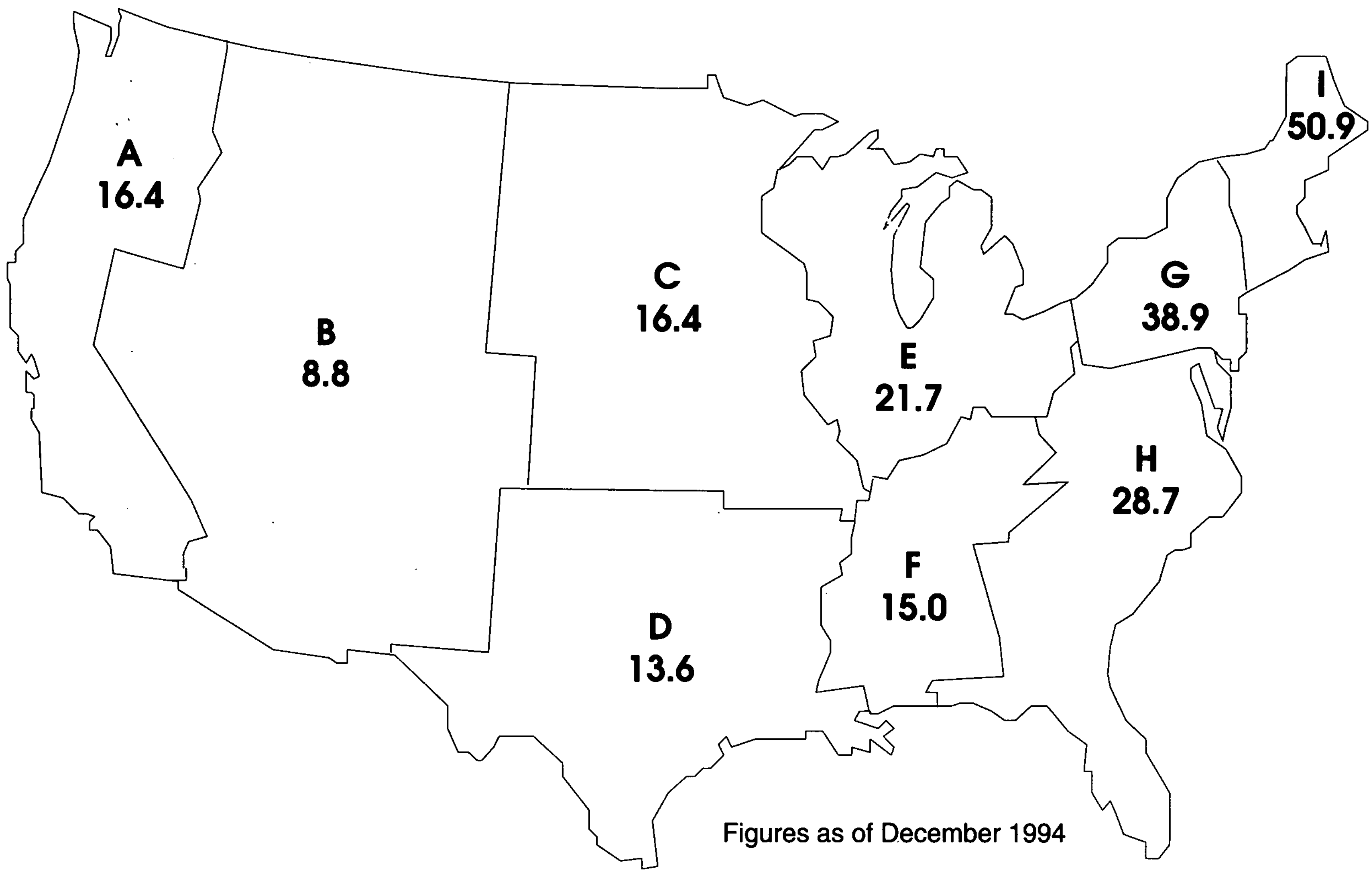
Nuclear Waste

Unit 1 Second Edition
Teacher Guide

Locations of Nuclear Powerplants

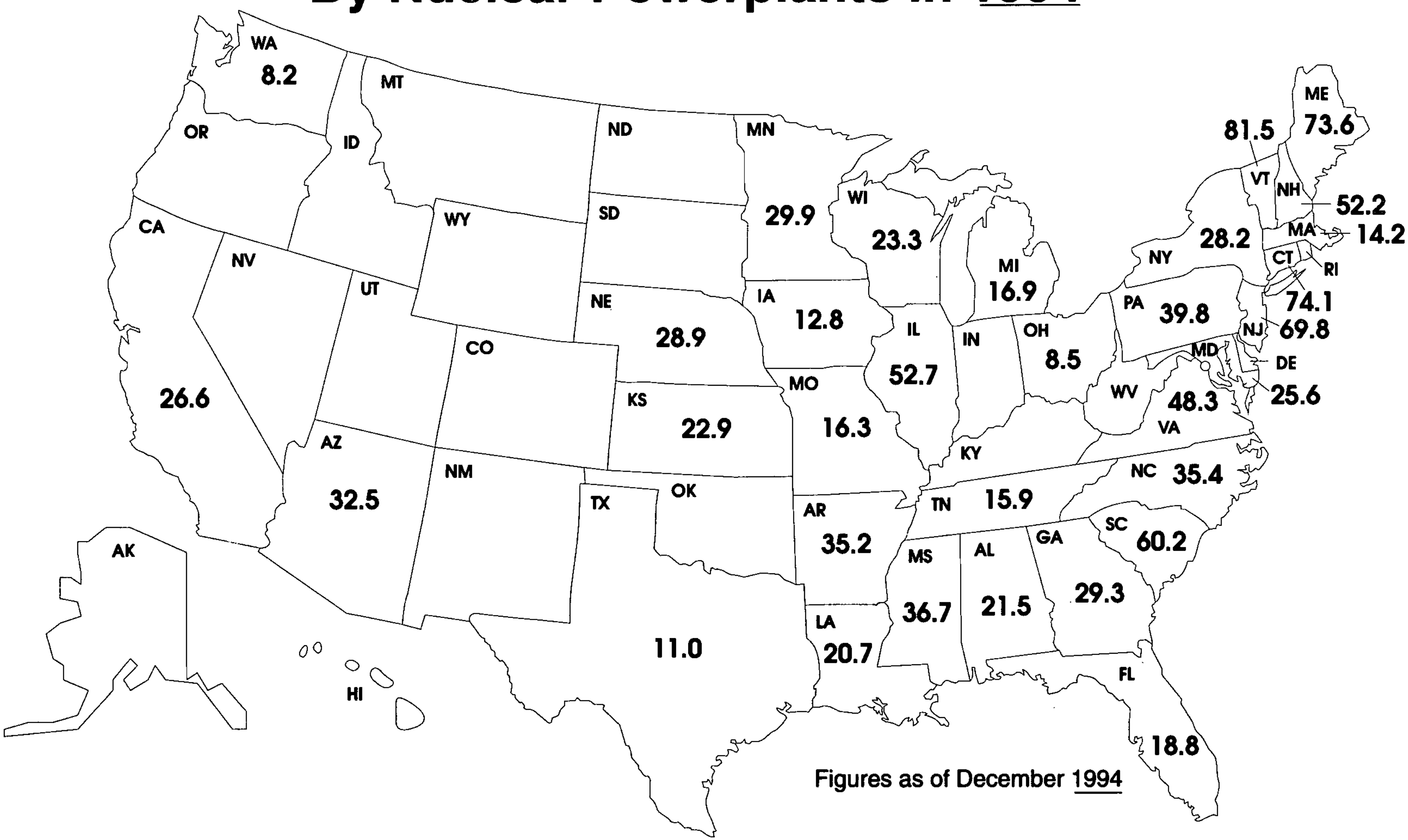


What Percentage of the Electricity Generated In Your Region In 1994 Came From Nuclear Energy?



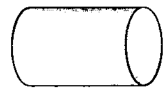
Figures as of December 1994

Percentage of Electricity Generated By Nuclear Powerplants in 1994

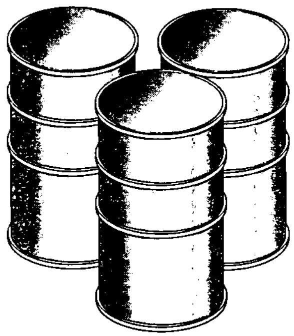


Figures as of December 1994

Energy Equivalents

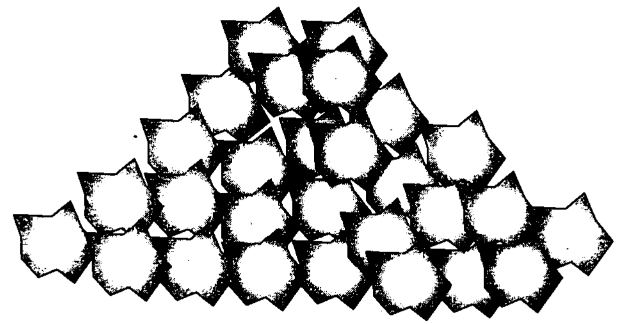


1 Uranium Fuel Pellet has as much energy available as...

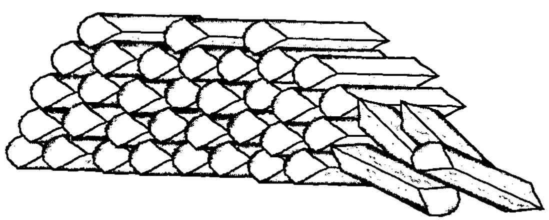


3 Barrels of Oil
(159 Liters or 42 Gallons)

OR

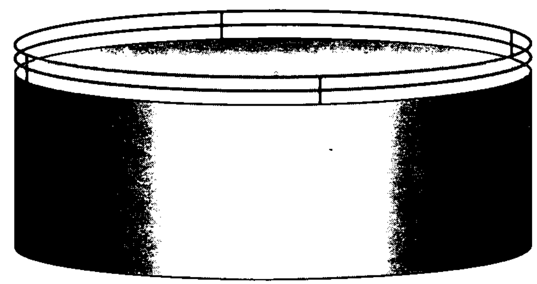


1 Ton of Coal



1 Cord of Wood
(2 1/2 Tons)

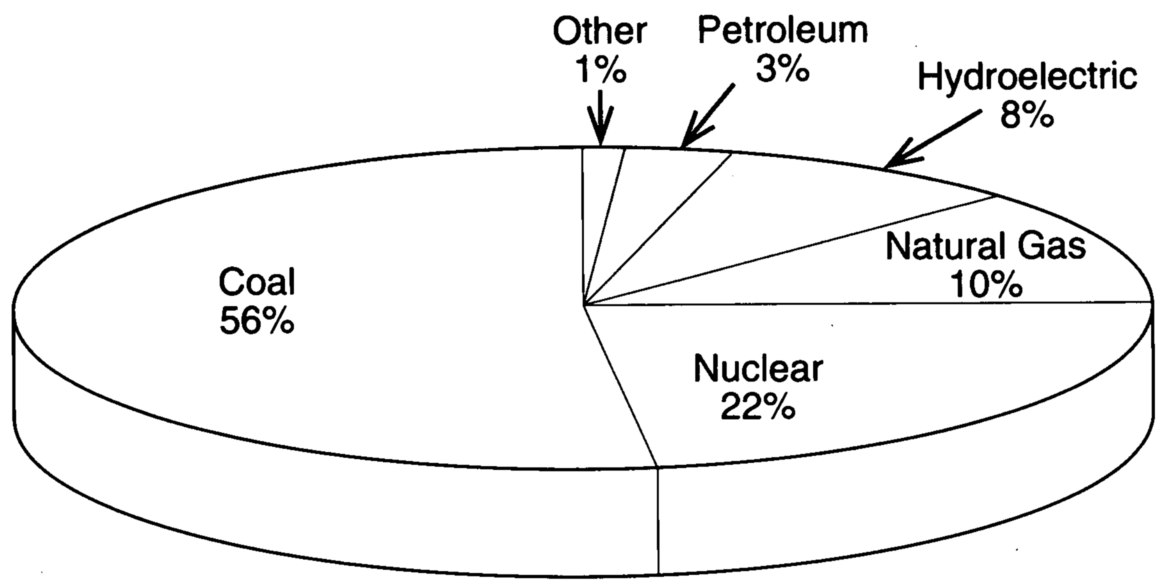
OR



481 Cubic Meters (17,000 Cubic Feet)
of Natural Gas

Uranium has essentially no other significant application in our society except for energy production.

Share of Electrical Generation By Power Source



Source: Energy Information Administration

Nuclear powerplants produced about 22% of our Nation's electricity in 1994.

Fission

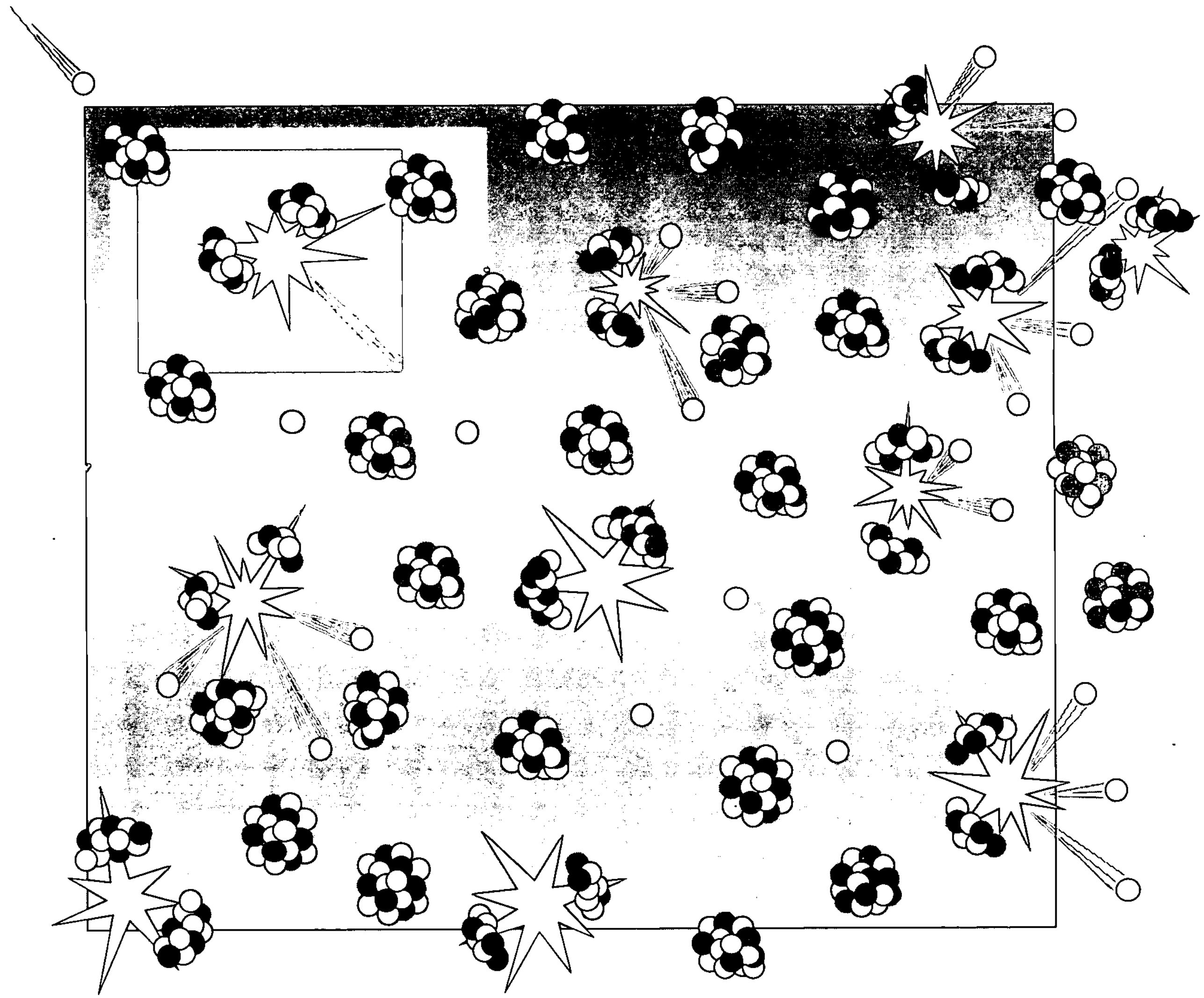
A neutron...

strikes the nucleus of a uranium-235 atom...

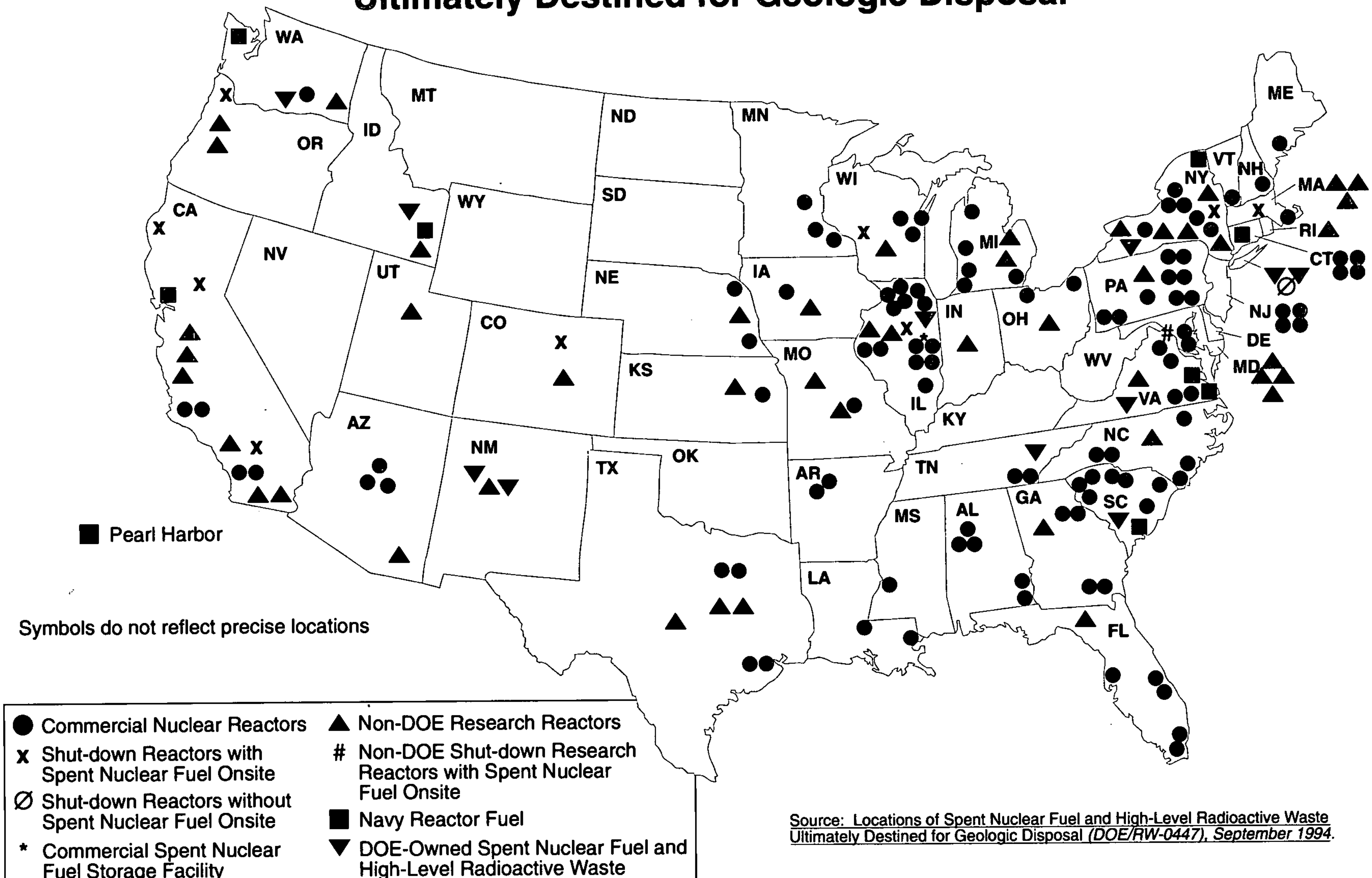
causing it to split apart, releasing energy as heat, fission products, and two or more neutrons...

that may cause additional uranium-235 nuclei to fission.

Eventually, when enough nuclei are split and enough neutrons released, the reaction perpetuates itself in a chain reaction.



Locations of Spent Nuclear Fuel and High-Level Radioactive Waste Ultimately Destined for Geologic Disposal



Source: Locations of Spent Nuclear Fuel and High-Level Radioactive Waste Ultimately Destined for Geologic Disposal *(DOE/RW-0447), September 1994*.

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
Alabama	Browns Ferry Plant 1, 2, 3 (Decatur) Joseph M. Farley 1, 2 (Dothan)			
Arizona	Palo Verde Station 1, 2, 3 (Wintersburg)	University of Arizona (Tucson)		
Arkansas	Arkansas Nuclear One 1, 2 (Russellville)			
California	Diable Canyon Plant 1, 2 (Avila Beach) Rancho Seco Plant 1* (Clay Station) San Onofre Plant 1*, 2, 3 (San Clemente) Humboldt Bay 3* (Eureka)	University of California (Irvine) General Electric (Pleasanton) McLellan Air Force Base ** (Sacramento) General Atomics 1, 2 (San Diego) Aerotest Research (San Ramon)	Mare Island (Vallejo)	
Colorado	Fort St. Vrain* (Platteville)	U.S. Geological Survey (Denver)		

* shut down reactors with spent nuclear fuel onsite
** status of spent fuel inventory to be determined

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
Connecticut	Haddam Neck Plant 1 (Haddam Neck) Millstone Plant 1, 2, 3 (Water Ford)		Knolls Atomic Power Laboratory (Windsor Locks)	
Florida	Crystal River Plant 3 (Red Level) St. Lucie Plant 1, 2 (Hutchinson Island) Turkey Point Plant 3, 4 (Florida City)	University of Florida (Gainesville)		
Georgia	Edwin I. Hatch Plant 1, 2 (Baxley) Alvin W. Vogtle 1, 2 (Waynesboro)	Georgia Institute of Technology (Atlanta)		
Hawaii			Pearl Harbor (Honolulu)	
Idaho		Idaho State University (Pocatello)	Idaho Naval Reactor (Idaho Falls)	Idaho National Engineering Laboratory (includes Argonne National Laboratory - West) (Idaho Falls)

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
Illinois	Clinton Plant 1 (Clinton) Quad Cities Nuclear Station 1, 2 (Cordova) Braidwood Plant 1, 2 (Braidwood) Zion Plant 1, 2 (Zion) Byron Plant 1, 2 (Byron) Dresden Station 1*, 2, 3 (Morris) LaSalle Station 1, 2 (Seneca) General Electric (Morris)**	University of Illinois 1, 2 (Urbana)		Argonne National Laboratory - East (Argonne)
Indiana		Purdue University (West Lafeyette)		
Iowa	Duane Arnold 1 (Palo)	Iowa State University (Ames)		
Kansas	Wolf Creek Plant 1 (Burlington)	Kansas State University (Manhattan)		

* shut down reactors with spent nuclear fuel onsite
** commercial spent fuel storage site

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Radioactive Waste
Louisiana	Waterford Plant 3 (Taft) River Bend Plant 1 (St. Francisville)			
Maine	Maine Yankee Plant 1 (Wiscasset)		Portsmouth Naval Shipyard (Kittery)	
Maryland	Calvert Cliffs Plant 1, 2 (Lusby)	University of Maryland (College Park) National Institute of Standards and Technology (Gaithersburg) Armed Forces Radiobiology Research Institute (Bethesda) U.S. Army Aberdeen Proving Grounds (Aberdeen)**		

** status of spent fuel inventory to be determined

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
Massachusetts	Pilgrim Plant 1 (Plymouth) Yankee Rowe Plant 1* (Rowe)	University of Massachusetts (Lowell) Massachusetts Institute of Technology (Cambridge) Worcester Polytechnical Institute (Worcester)		
Michigan	Enrico Fermi 2 (Newport) Donald C. Cook Plant 1, 2 (Bridgman) Palisades Plant 1 (South Haven) Big Rock Point Plant 1 (Charlevoix)	University of Michigan (Ann Arbor) Dow Chemical (Midland)		
Minnesota	Monticello Plant 1 (Monticello) Prairie Island Plant 1, 2 (Red Wing)			
Mississippi	Grand Gulf Station 1 (Port Gibson)			

* shut down reactors with spent nuclear fuel onsite

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
Missouri	Callaway Plant 1 (Fulton)	University of Missouri (Columbia) University of Missouri (Rolla)		
Nebraska	Cooper Plant 1 (Brownville) Fort Calhoun Plant 1 (Fort Calhoun)	Veterans Administration (Omaha)		
New Hampshire	Seabrook Station 1 (Seabrook)			
New Jersey	Oyster Creek Plant 1 (Forked River) Salem Generating Station 1, 2*** (Hancocks Bridge) Hope Creek Generating Station 1*** (Hancocks Bridge)			

*** Salem and Hope Creek Generating Stations, NJ, are located on the same site.

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
New Mexico		University of New Mexico (Albuquerque)		Los Alamos National Laboratory/Omega West Reactor (Los Alamos) Sandia National Laboratory (Albuquerque)
New York	Nine Mile Point Plant 1, 2 (Lycoming) Indian Point Plant 1*, 2 (Buchanan) Indian Point Plant 3 (Buchanan) James A. Fitzpatrick Nuclear Plant 1 (Lycoming) Robert E. Ginna Plant 1 (Ontario) Shoreham Station@ (Wading River)	State University of New York (Buffalo) Cornell University 1, 2 (Ithaca) Manhattan College (Bronx) Rensselaer Polytechnic Institute (Troy)	Knolls Atomic Power Laboratory (West Milton)	Brookhaven National Laboratory (Upton) (High-flux Beam Reactor) (Brookhaven Medical Research Reactor) West Valley Demonstration Project (West Valley)

* shut down reactors with spent fuel onsite

@ shut down reactor/spent nuclear fuel has been shipped to Limerick Generating Station, PA as of May 1994

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
North Carolina	Brunswick Plant 1, 2 (Southport) Shearon Harris 1 (Newhill) W.B. McGuire Plant 1, 2 (Huntersville)	North Carolina State University (Raleigh)		
Ohio	Davis Besse Plant 1 (Toledo) Perry Plant 1 (Perry)	Ohio State University (Columbus)		
Oregon	Trojan Plant 1* (Ranier)	Oregon State University (Corvallis) Reed College (Portland)		
Pennsylvania	Susquehanna Plant 1, 2 (Berwick) Limerick Generating Station 1, 2 (Linfield) Peach Bottom Station 2, 3 (Delta) Three Mile Island 1 (Middletown) Beaver Valley Plant 1, 2 (Shippingport)	Pennsylvania State University (State College)		

* shut down reactors with spent fuel onsite

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Radioactive Waste
Rhode Island		Rhode Island Nuclear Science Center (Narragansett)		
South Carolina	H.B. Robinson Plant 2 (Hartsville) Catawba Plant 1, 2 (Clover) Oconee Plant 1, 2, 3 (Seneca) Virgil C. Summer 1 (Parr)		Charleston Naval Shipyard (Charleston)	Savannah River Site (Aiken)
Tennessee	Sequoyah Plant 1, 2 (Soddy-Daisy)			Oak Ridge National Laboratory (Oak Ridge)
Texas	Comanche Peak Plant 1, 2 (Glen Rose) South Texas Plant 1, 2 (Palacios)	Texas A&M University 1, 2 (College Station) University of Texas (Austin)		
Utah		University of Utah 1 (Salt Lake City)		
Vermont	Vermont Yankee 1 (Vernon)			

State	Commercial Reactors	Non-DOE Research Reactors	Navy Reactor Fuel	DOE-Owned Spent Fuel and High-Level Redioactive Waste
Virginia	North Anna Power Plant 1, 2 (Mineral) Surry Power Plant 1, 2 (Surry)	University of Virginia 1 (Charlottesville)	Norfolk Naval Shipyard (Portsmouth) Newport News Shipbuilding (Newport News)	B&W Nuclear Environmental Services, Inc. (Lynchburg)
Washington	Washington Nuclear Plant 2 (Richland)	Washington State University (Pullman)	Puget Sound Naval Shipyard (Bremerton)	Hanford Reservation (Richland)
Wisconsin	Point Beach Plant 1, 2 (Two Rivers) Kewaunee Plant 1 (Carlton) La Crosse* (Genoa)	University of Wisconsin (Madison)		
District of Columbia		Catholic University+		

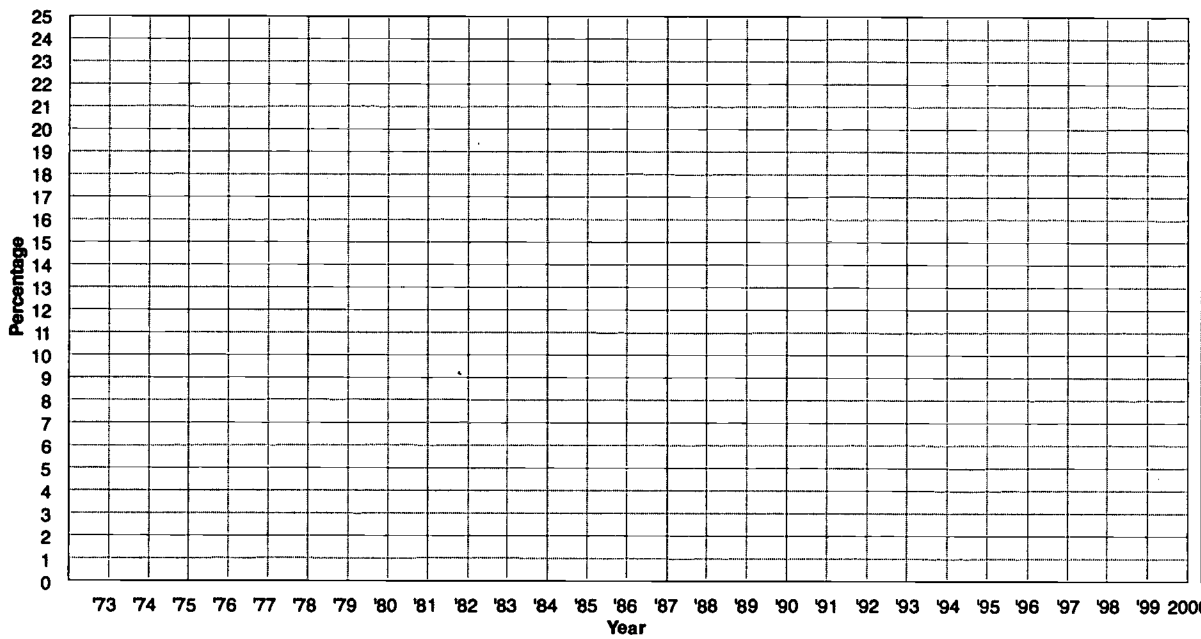
* shut down reactors with spent fuel onsite

ELECTRICITY FROM NUCLEAR ENERGY

1. Briefly explain how electricity is important in your daily life.

____

____



Percentage by Year	
1973	4.5
1974	6.1
1975	9.0
1976	9.5
1977	11.8
1978	12.5
1979	11.4
1980	11.0
1981	11.9
1982	12.6
1983	12.7
1984	13.6
1985	15.5
1986	16.6
1987	17.7
1988	19.5
1989	19.0
1990	20.6
1991	21.7
1992	22.1
1993	21.2
1994	22.0
1995	
1996	
1997	
1998	
1999	
2000	

2. The annual percentages of electricity produced by nuclear powerplants in the United States from 1973 to 1994 are given above. Graph the data above. Then in a sentence explain what the graph shows.

____

____

3. What do you think that the graph will look like in 2000? Why?

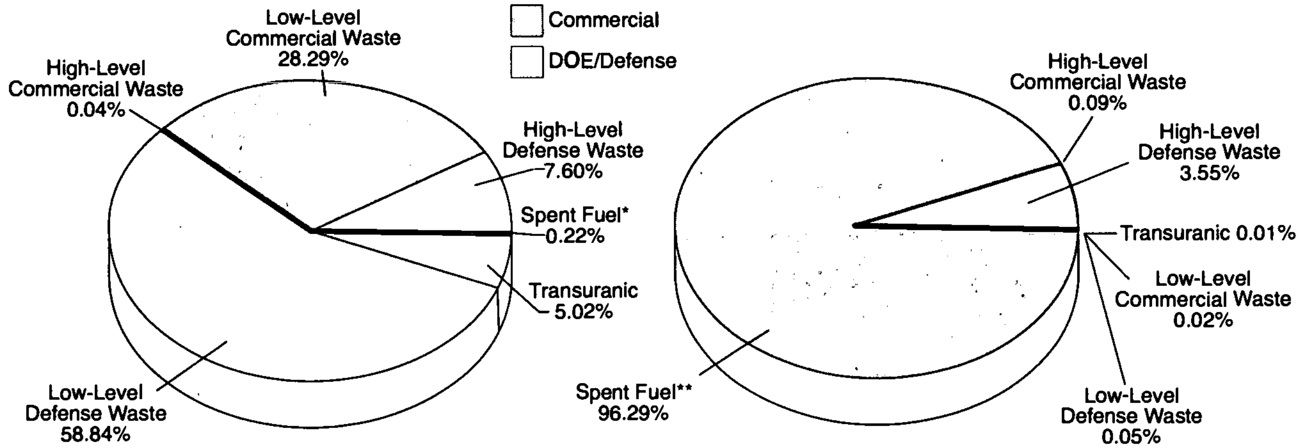
____

____

4. Discuss the role nuclear energy plays in providing electricity for the United States. How does this affect you?

5. How is electricity generation related to nuclear waste?

Radioactive Wastes: Volumes and Radioactivities (1993)



**Includes spacing between fuel assembly rods. DOE/Defense Program spent fuel to be reprocessed is not shown.*

***DOE/Defense Program spent fuel to be reprocessed is not shown.*

Directions: Using the information in the reading lesson and the pie charts above, answer the questions.

1. As of 1994, more than ______ percent of our Nation's electricity was generated by nuclear powerplants.

2. What percentage of the total amount of radioactive waste is:
   a. low-level? ____________________ b. high-level? ____________________
   c. spent fuel? ____________________ d. transuranic? ____________________

3. What is the source of the greatest volume of high-level waste? ______________ %? ________

4. What type of waste represents:
   a. the greatest amount of radioactivity? ____________________ %? ________
   b. second greatest amount of radioactivity? ____________________ %? ________

5. What two sources represent the least radioactivity?
   a. ______________ %? ______ b. ______________ %? ________

6. a. Although spent fuel is _______ of the accumulation of radioactive waste, it contains _______ of the radioactivity.
   b. Low-level defense and commercial wastes represent _______ of the volume of waste but only _______ of the radioactivity.

7. What is the significance of the information in these pie charts?

____

____

____

____

NUCLEAR WASTE: WHAT IS IT? WHERE IS IT?

A. In the blanks provided, write the number of the statement that best describes the terms that are listed. A response may be used only once. All responses will not be used.

TERMS

___A. Geologic Repository

___B. Spent Fuel

___C. Fuel Rods

___D. Nuclear Waste

___E. Low-Level Waste

___F. Classification of Waste

___G. Compact

ANSWERS

1. byproduct from using radioactive material
2. discarded protective clothing from "housekeeping" functions of commercial and university nuclear facilities
3. depends on its origin, level of radioactivity, and potential hazard
4. deep underground facility
5. organization of States with purpose of providing for disposal of low-level waste from all members
6. has been used in a nuclear reactor and doesn't contribute efficiently to the nuclear chain reaction
7. hollow metal tubes containing nuclear powerplant fuel
8. spent fuel and defense high-level waste will be disposed of in a geologic repository

B. List the four categories of nuclear waste and give the source or sources for each type.

1. ________ ____________________________ ____________________

2. ________ ____________________________ ____________________

3. ________ ____________________________ ____________________

4. ________ ____________________________ ____________________

C. Arrange the following phrases in the correct order. Then draw a diagram that illustrates the sentence you have made.

causing the nucleus to split apart
a neutron
releasing energy, fission products, and more neutrons
strikes the nucleus of a uranium-235 atom

____

____

D. Indicate whether each statement is true (T) or false (F) by writing the correct letter in the blank. If the statement is false, correct it to make it true.

___ 1. The U.S. Department of Energy (DOE) is responsible for establishing a system for the disposal of high-level radioactive waste.

___ 2. Mill tailings contain small amounts of radium that decay to radon, a radioactive gas.

___ 3. Transuranics represent the most radioactive category of nuclear waste.

___ 4. All radioactive waste must be handled by remote control from behind heavy shielding.

___ 5. Nuclear fuel burns.

E. Complete each of the following sentences.

1. Nuclear waste requires special disposal because ______________________________

____

____

2. The amended Nuclear Waste Policy Act directed the U.S. Department of Energy to perform site characterization on ______________________ as a candidate site for a geologic repository.

3. Some high-level waste may contain elements that decay very slowly and may remain radioactive for ____________________ of years.

4. In <u>1994</u>, over <u>109</u> nuclear powerplants <u>operating</u> in 35 States generated more than ________ percent of the Nation's electricity.

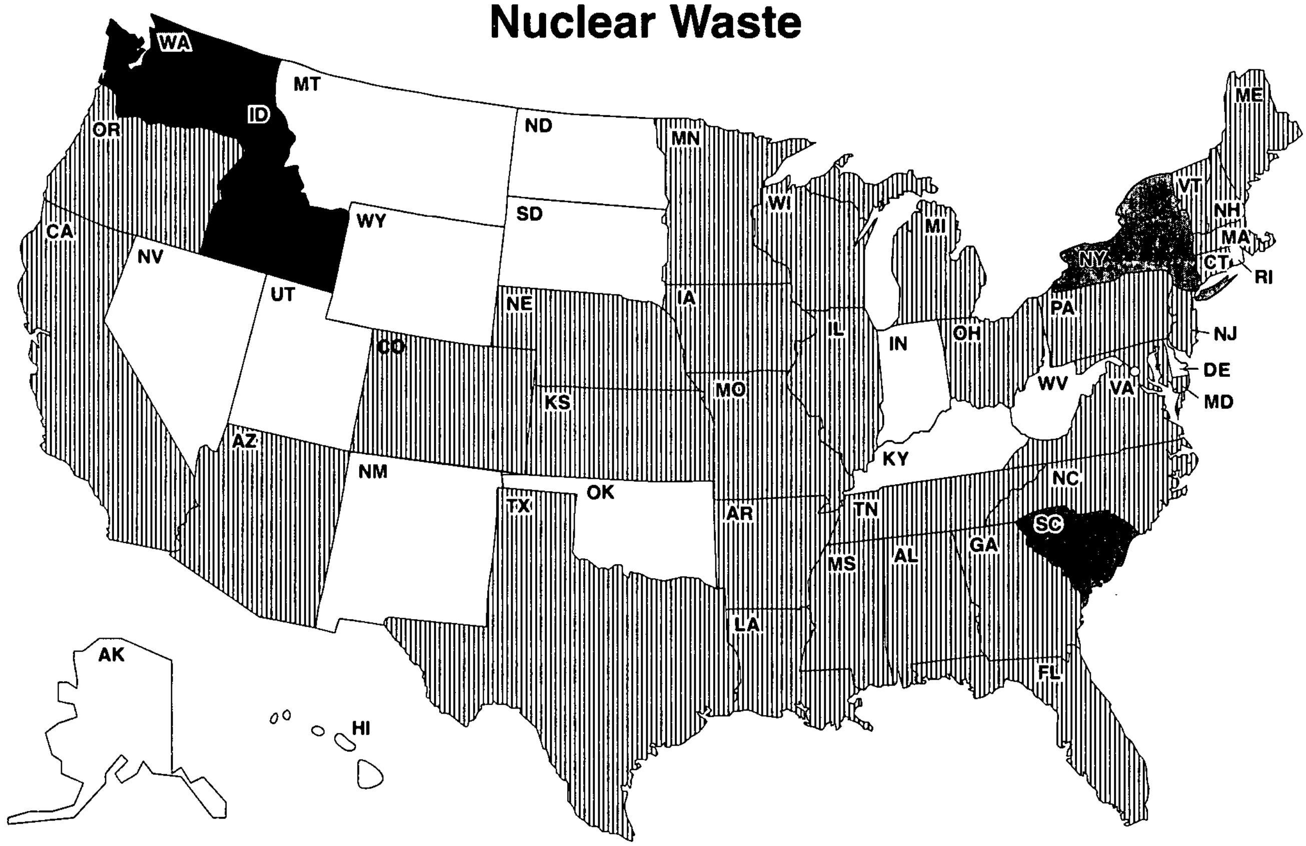
5. Approximately 8,000 to 9,000 metric tons of defense high-level waste are currently stored at three DOE Sites: the ____________________ ; the ____________________ ; and the ________________________ .

GEOGRAPHIC DISTRIBUTION OF COMMERCIAL SPENT FUEL AND COMMERCIAL AND DEFENSE HIGH-LEVEL NUCLEAR WASTE

In 1993, commercial spent fuel was stored in more than half of the States in the Nation. High-level waste from defense activities was stored in three States in 1991 and will continue to be stored there through the year 2000. In addition, a small amount of waste (1,729 cubic meters) that resulted from the reprocessing of commercial spent fuel was stored in West Valley, New York in 1991.

Fill in the map below to show the three groupings of States indicated by the map key. To make your groupings, use the information in the paragraph above and information in the reading titled *Nuclear Waste: What Is It? Where Is It?* The information in the reading is in the table titled *Spent Fuel Storage - 1993 and 2003* (Section 1.14) and the discussion of storage of high-level defense waste (Section 1.15). Read these sections again before beginning to work on the map.

Geographic Distribution of Commercial Spent Fuel and Commercial and Defense High-Level Nuclear Waste



KEY: Commercial spent fuel and defense high-level waste (4 States)

Only spent nuclear fuel stored

No spent fuel or commercial high-level waste

GEOGRAPHIC DISTRIBUTION OF COMMERCIAL SPENT FUEL AND COMMERCIAL AND DEFENSE HIGH-LEVEL NUCLEAR WASTE

Directions: Using the completed map, the activity introduction, and information about *metric tons* of spent fuel for other high-level waste from the tables in the reading lesson, answer the questions below.

1. What is commercial waste? ____________________

   ____

   What is defense high-level radioactive waste? ____________________

   ____

2. In how many States was commercial spent fuel being stored in 1993? __________

3. Was spent fuel stored in the State you live in during 1993? __________

4. If yes, how many metric tons? __________

5. If not, do you border a State that does? __________

6. In which three States was defense high-level nuclear waste stored in 1991? (Use State abbreviations.) __________

7. In which State was commercial high-level waste (reprocessed spent fuel) other than spent fuel stored in 1993? __________

8. Which four States had the largest accumulations (in *metric tons*) of spent fuel in 1993? (Use State abbreviations.) __________

   Which five States are projected to have the largest accumulations (in *metric tons*) by 2003? (Use State abbreviations.) __________

9. Commercial spent fuel and other high-level nuclear waste were not stored in 1993 and are not projected to be stored by the year 2003 in the following 15 States: (Use State abbreviations.)

   ____

   ____

10. In your opinion, what is the significance of the information in the map and in the tables?

    ____

    ____

    ____

WHAT DOES NUCLEAR WASTE HAVE TO DO WITH ME?

You may wish to use the attached list of utilities that own a nuclear powerplant and addresses to provide students with information which will enable them to contact nuclear powerplants and/or utilities in your area, State and region. It is suggested that students write or visit the powerplant of their choice and request answers to the following questions:

1. What area does the utility serve?
2. What energy sources does the utility use to generate electricity?
3. What percent of the electricity is produced by nuclear energy?
4. Does the utility ever sell electricity to utilities that have no nuclear powerplants?
5. How much spent fuel is stored at the powerplant?
6. How much additional storage capacity is there at the site?
7. Has the utility rearranged the fuel or consolidated fuel to gain additional space?
8. Has the utility shipped spent fuel to another site? Are there plans to do so?
9. How much has the utility paid into the Nuclear Waste Fund?
10. What are the plans for meeting future demand for electricity?

It might be interesting to assign different powerplants to different students or groups of students. Once information has been gathered, ask students to share the responses they received with the entire class. Discuss any differing responses and try to determine, as a class, what the reason might be for the differences among powerplants. Have students draw a conclusion relative to the necessity for development of a safe and environmentally acceptable method for the permanent disposal of radioactive waste based upon the answers they received from the various powerplants contacted.

ALABAMA POWER COMPANY
Farley Nuclear Plant Visitor's Center
Highway 95 South
Columbia, AL 36319

APPALACHIAN POWER COMPANY
John Amos Plant
P.O. Box 4000
St. Albans, WV 25177

ARIZONA PUBLIC SERVICE COMPANY
Palo Verde Nuclear Generating Station Visitors Center
5801 S. Wintersburg Road
Tonopah, AZ 85354

BALTIMORE GAS AND ELECTRIC COMPANY
Calvert Cliffs Visitors Center
1650 Calvert Cliffs Parkway
Lusby, MD 20657

BOSTON EDISON COMPANY
Pilgrim Nuclear Power Station
600 Rocky Hill Road
Plymouth, MA 02360

CAROLINA POWER AND LIGHT COMPANY
Brunswick Plant Visitor's Center
P.O. Box 10488
Southport, NC 28461

HARRIS VISITOR CENTER
Box 327
New Hill, NC 27562

CENTRAL HUDSON GAS & ELECTRIC CORPORATION
Roseton Generating Station
594 River Road
Newburgh, NY 12550

CENTRAL MAINE POWER COMPANY
Maine Yankee Information Center
P.O. Box 408
Wiscasset, ME 04578

CENTRAL POWER AND LIGHT COMPANY
South Texas Project Visitor Center
P.O. Box 246
Wadsworth, TX 77483

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
Conservation Center
405 Lexington Avenue
New York, NY 10174

CONNECTICUT YANKEE ATOMIC POWER CO.
Information and Science Center
362 Injun Hollow Road
Haddam Neck, CT 06424

DETROIT EDISON COMPANY
Fermi 2 Visitors Center
6400 N. Dixie Highway
Newport, MI 48166

DUKE POWER COMPANY
The World of Energy at Keowee-Toxaway
7812 Rochester Highway
Seneca, SC 29672

ENERGY EXPLORIUM AT LAKE NORMAN
13339 Hagers Ferry Road
MG03E
Huntersville, NC 28078

ENERGY QUEST AT CATAWBA
4850 Concord Road
York, SC 29745

EL PASO ELECTRIC COMPANY
Newman Power Station
P.O. Box 982
El Paso, TX 79960

FLORIDA POWER CORPORATION
The Power Place
15760 West Power Line Street, SA1E
Crystal River, FL 34428-6708

GEORGIA POWER COMPANY
Edwin I. Hatch Visitors Center
Route 1, Box 720
US Highway 1 North
Baxley, GA 31513

TERRORA EDUCATION CENTER
Terrora Park
P.O. Box 9
Tallullah Falls, GA 30573

GENERAL PUBLIC UTILITIES NUCLEAR CORPORATION
Three Mile Island Visitors' Center
P.O. Box 480
Middletown, PA. 17057

GULF STATES UTILITIES COMPANY
The River Bend Energy Center
P.O. Box 220
St. Francisville, LA 70775

EDISON PLAZA MUSEUM
P.O. Box 3652
Beaumont, TX 77706

HOUSTON LIGHTING & POWER COMPANY
Energy Information Center
P.O. Box 1700
Houston, TX 77251

ILLINOIS POWER COMPANY
Illinois Power, Energy & Environmental Center
P.O. Box 637
Clinton, IL 61727

INDIANA-MICHIGAN POWER
Cook Energy Information Center
P.O. Box 115
Bridgman, MI 49106

IOWA-ILLINOIS GAS AND ELECTRIC COMPANY
Nuclear Information Center
22511 206th Avenue North
Cordova, IL 61242

JERSEY CENTRAL POWER AND LIGHT COMPANY
Energy Spectrum
P.O. Box 592
Forked River, NJ 08731

KANSAS CITY POWER AND LIGHT COMPANY
Jeffery Energy Center
P.O. Box 40
St. Mary's, KS 66536

LOUISIANA POWER AND LIGHT COMPANY
Waterford III Energy Education Center
P.O. Box B
Killona, LA 70066

NEW ENGLAND POWER
25 Research Drive
Westborough, MA 01582

NEW ORLEANS PUBLIC SERVICE COMPANY, INC.
2330 Canal Street
New Orleans, LA 70160

NEW YORK POWER POOL
Visitor's Center
3890 Carman Road
Schenectady, NY 12303

NEW YORK STATE ELECTRIC & GAS CORPORATION
Energy Centers
4500 Vestal Parkway East
P.O. Box 3607
Binghamton, NY 13902-3607

NIAGARA MOHAWK POWER CORPORATION
The Energy Center
P.O. Box 81
Lycoming, NY 13093

NORTHEAST UTILITIES COMPANY
Millstone Energy Center
278 Main Street
Niantic, CT 06357

NORTHERN STATES POWER COMPANY
Cost Control Center
1414 W. Hamilton Avenue
Eau Claire, WI 54701

PENNSYLVANIA POWER AND LIGHT COMPANY
Susquehanna Energy Information Center
P.O. Box 467
Berwick, PA 18603

PHILADELPHIA ELECTRIC COMPANY
Limerick Energy Information Center
298 Longview Road
Linfield, PA 19468

MUDDY RUN INFORMATION CENTER
172 Bethesda Church Road, West
Holtwood, PA 17532

NORTH ATLANTIC ENERGY SERVICE CORP.
The Science and Nature Center at Seabrook Station
U.S. Route 1, P.O. Box 300
Seabrook, NH 03874

PUBLIC SERVICE ELECTRIC AND GAS COMPANY
Nuclear Public Information Office
P.O. Box 236, MCN08
Hancocks Bridge, NJ 08038

UNION ELECTRIC COMPANY
Callaway Visitors Center
P.O. Box 620
Fulton, MO 65251

VERMONT YANKEE NUCLEAR POWER CORPORATION
Energy Information Center
P.O. Box 157
Vernon, VT 05354

VIRGINIA POWER
North Anna Nuclear Information Center
P.O. Box 402
Mineral, VA 23117

SOUTHERN COMPANY SERVICES
Corporate Library
P.O. Box 2625
Birmingham, AL 35202

SURRY NUCLEAR INFORMATION CENTER
P.O. Box 315
Surry, VA 23883

TU ELECTRIC
Visitors Information Center
Comanche Peak Steam Electric Station
P.O. Box 1002
Glen Rose, TX 76043

TVA ENERGY CENTER
1101 Market Street, BR4F
Chattanooga, TN 37402

WISCONSIN ELECTRIC POWER COMPANY
Point Beach Energy Center
6600 Nuclear Road
Two Rivers, WI 54241

WOLF CREEK NUCLEAR OPERATING CORPORATION
Dwight D. Eisenhower Learning Center
1675 Milo Lane NE
Burlington, KS 66839

YANKEE ATOMIC ELECTRIC COMPANY
Visitors Center
48 Yankee Road
Rowe, MA 01367

REGIONAL ELECTRICITY GENERATION

A pie chart is a circle-shaped graph. It is easy to read and useful for understanding how different sets of information relate to each other as a whole. Creating a pie chart involves many steps. In this activity you will make a pie chart using data in the table entitled *Net Generation by Energy Source, Census Division, and State, 1994*. On this table, the 50 States are divided into 10 census groups. You will be assigned one census division by your teacher.

Follow the directions below to complete the table and construct a pie chart. Use data for your census division from *Net Generation by Energy Source, Census Division, and State, 1994*.

1. Use *Net Generation by Energy Source, Census Division, and State, 1994* to fill in Column II. Then calculate the total gigawatthours of electricity produced by your census division in 1994. A gigawatthour is equal to one million kilowatt hours.

2. In Column III, convert each value in Column II to a percent. Treat NA (not applicable) values as zero for this exercise. Round all answers to the nearest 100th of a percent. Because many of the numbers in *Net Generation by Energy Source, Census Division, and State, 1994* have been rounded, the sum of the percentages you calculate may not be precisely 100 percent.

3. A complete circle contains 360 degrees; therefore, it will be necessary to convert the percentages in Column III to degrees for Column IV. Round your answers to the nearest whole degree. If you calculate a value that is greater than 0 but less than 0.5, round it to one degree. The sum of the degrees you calculate should be approximately 360.

4. Using a protractor, draw your pie chart in the blank circle.

5. Label each division (each slice of the pie) with the energy source and the percentage that it represents. Be sure to give your pie chart an appropriate, yet creative, title in the space provided.

Net Generation by Energy Source, Census Division, and State, 1994*
(Gigawatthours) = Million Kilowatthours

Census Division State	Coal 1994	Petroleum 1994	Gas 1994	Nuclear 1994	Hydroelectric 1994	Other 1994	Total 1993
New England	**15,495**	**15,009**	**4,624**	**41,206**	**4,125**	**511**	**80,970**
Connecticut	2,104	3,354	732	20,160	412	439	27,201
Maine	NA	702	NA	6,632	1,682	NA	9,016
Massachusetts	10,210	9,561	3,736	3,895	100	NA	27,502
New Hampshire	3,182	1,353	115	6,204	1,036	NA	11,888
Rhode Island	NA	34	35	NA	NA	NA	69
Vermont	NA	6	6	4,316	895	72	5,294
Middle Atlantic	**119,434**	**17,836**	**22,117**	**118,561**	**26,545**	**11**	**304,504**
New Jersey	4,646	1,656	3,440	22,129	-167	NA	31,705
New York	20,859	10,998	17,464	29,225	25,200	11	103,757
Pennsylvania	93,928	5,182	1,213	67,207	1,512	NA	169,043
East North Central	**383,432**	**2,617**	**4,547**	**109,267**	**3,280**	**265**	**503,410**
Illinois	61,214	1,208	2,624	72,654	45	NA	137,745
Indiana	102,043	209	826	NA	407	NA	103,485
Michigan	67,539	656	657	14,144	725	NA	83,721
Ohio	117,354	372	153	10,952	189	NA	129,021
Wisconsin	35,283	172	287	11,516	1,914	265	49,438
West North Central	**171,911**	**1,573**	**3,439**	**41,212**	**12,025**	**458**	**230,619**
Iowa	26,499	78	199	4,107	1,053	28	31,965
Kansas	26,489	83	2,183	8,529	NA	NA	37,284
Minnesota	26,400	597	452	12,224	831	414	40,917
Missouri	48,588	731	338	10,006	1,844	7	61,514
Nebraska	14,002	18	259	6,345	1,312	9	21,946
North Dakota	27,100	47	NA	NA	1,856	NA	29,004
South Dakota	2,833	19	8	NA	5,129	NA	7,989
South Atlantic	**335,071**	**42,719**	**26,458**	**169,081**	**15,746**	**NA**	**589,074**
Delaware	4,754	1,902	2,127	NA	NA	NA	8,783
District of Columbia	NA	274	NA	NA	NA	NA	274
Florida	60,770	33,330	20,734	26,682	274	NA	141,790
Georgia	64,728	153	80	28,927	4,857	NA	98,745
Maryland	25,394	4,134	993	11,222	2,010	NA	43,752
North Carolina	53,234	199	69	32,346	5,606	NA	91,455
South Carolina	26,678	101	279	44,475	2,347	NA	73,880
Virginia	22,449	2,374	2,152	25,429	289	NA	52,693
West Virginia	77,063	251	25	NA	363	NA	77,703
East South Central	**203,689**	**1,676**	**7,111**	**42,027**	**25,841**	**NA**	**280,344**
Alabama	62,768	121	373	20,480	11,429	NA	95,171
Kentucky	79,899	154	31	NA	4,014	NA	84,097
Mississippi	8,890	1,106	6,612	9,615	NA	NA	26,222
Tennessee	52,132	296	95	11,932	10,399	NA	74,854
West South Central	**189,967**	**1,097**	**145,998**	**54,347**	**7,457**	**303**	**399,170**
Arkansas	19,781	96	2,285	13,924	3,462	NA	39,548
Louisiana	20,125	680	26,586	12,357	NA	NA	59,748
Oklahoma	27,454	11	15,451	NA	2,465	NA	45,381
Texas	122,607	309	101,677	28,067	1,530	303	254,494
Mountain	**202,183**	**423**	**9,563**	**23,171**	**28,302**	**237**	**263,878**
Arizona	38,072	128	2,162	23,171	7,670	NA	71,204
Colorado	31,401	9	374	NA	1,540	NA	33,324
Idaho	NA	NA	NA	NA	7,303	NA	7,303
Montana	16,488	18	61	NA	8,096	42	24,705
Nevada	15,325	167	3,174	NA	1,866	NA	20,531
New Mexico	26,752	23	3,030	NA	213	NA	30,018
Utah	32,764	30	750	NA	716	195	34,455
Wyoming	41,380	47	13	NA	897	NA	42,337
Pacific Contiguous	**13,614**	**1,874**	**64,492**	**40,492**	**118,931**	**7,163**	**246,565**
California	NA	1,863	61,530	33,752	22,824	6,767	126,737
Oregon	3,814	5	2,755	NA	30,916	NA	37,490
Washington	9,800	6	206	6,740	65,190	396	82,338
Pacific Non-contiguous	**295**	**6,477**	**2,681**	**NA**	**1,364**	**NA**	**10,818**
Alaska	295	441	2,681	NA	1,345	NA	4,762
Hawaii	NA	6,036	NA	NA	19	NA	6,055
U.S. Total	**1,635,090**	**91,303**	**291,031**	**639,364**	**243,616**	**8,948**	**2,909,352**

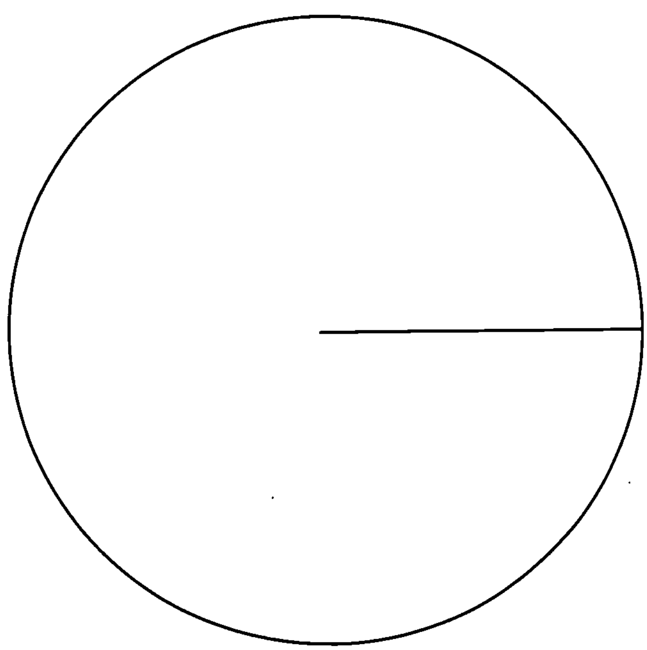
* *Data for 1994 are preliminary.*
** *Value less than 0.5 gigawatt hours.*
Notes: Negative generation denotes that electric power consumed for plant use exceeds gross generation.
Totals may not equal sum of components because of independent rounding.
Source: Energy Information Administration, Form EIA-759, "Monthly Power Plant Report," December 1994.

REGIONAL ELECTRICITY GENERATION

Census Division: ____________________

I **Energy Source**	II **Electricity Produced** (Gigawatthours)	III **Percent** (Nearest 100th)	IV **Degrees** (Nearest whole degree)
Coal	________	________	________
Petroleum	________	________	________
Gas	________	________	________
Nuclear	________	________	________
Hydroelectric	________	________	________
Other	________	________	________
Total	________	________	________

Title: ____________________



MAKING A PIE CHART – UNITED STATES

I Energy Source	II Electricity Produced (Million Kilowatthours)	III Percent (Nearest 10th)	IV Degrees (Nearest whole degree)
Coal	1,635,090	56.2	202
Petroleum	91,303	3.1	11
Gas	291,031	10.0	36
Nuclear	639,364	22.0	79
Hydroelectric	243,616	8.4	30
Other	8,948	0.3	1
Total	**2,909,352**	**100.00**	**359**

Converting Electricity Produced to a Percent

$$\frac{x}{100} = \frac{\text{number million kilowatt hours/source}}{\text{total number million kilowatthours}}$$

Example: Coal - United States

Set up the proportion: $\frac{x}{100} = \frac{1,635,090}{2,909,352}$ (100)

Cross multiply: $2,909,352(x) = 1,635,090$

$2,909,352(x) = 163,509,000$

Solve for x: $\frac{2,909,352(x)}{2,909,352} = \frac{163,509,000}{2,909,352}$

$x = 56.2\%$

Converting Electricity Produced to Degrees

$$\frac{x}{360} = \frac{\text{percent}}{100}$$

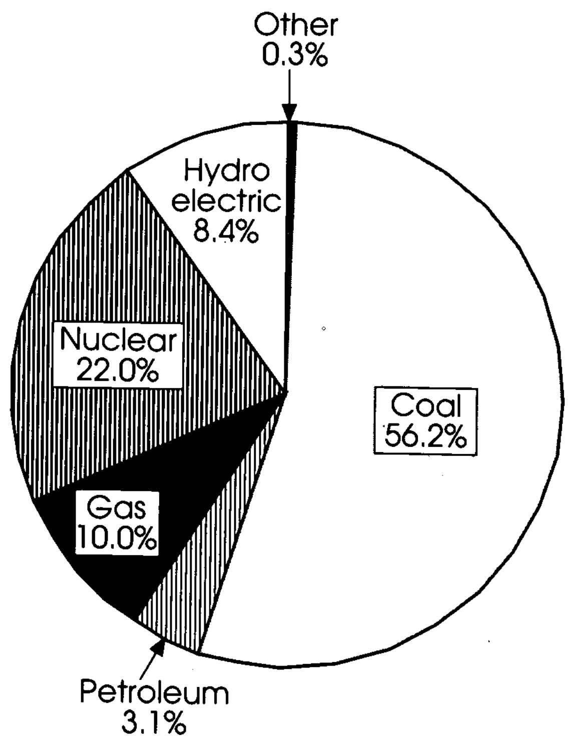
Set up the proportion: $\frac{x}{360} = \frac{56.2\%}{100}$

Cross multiply: $(100)(x) = (56.2)(360)$

$100(x) = 20,232.0$

Solve for x: $\frac{100(x)}{100} = \frac{20,232.0}{100}$

$x = 202°$



INVENTORIES OF SPENT FUEL

A thematic map provides information about a single topic, such as inventories of spent fuel. Thematic maps with shaded or colored areas are choropleth maps. Their shading enables map readers to see patterns quickly, and for this reason, shading is usually progressively darker as data values increase.

The spent fuel inventory data can first be visualized on a number line. The pre-established number line and legend provides for well-distributed categories of volume spans. You can look off the number line when coloring in your map.

Directions: Fill in the number line and choropleth map showing inventories of spent fuel in the United States. Use the data about metric tons of spent fuel from the table on the enrichment activity entitled *Spent Fuel Inventories Number Line*.

Number Line:

1. The tick marks on the number line have been labeled by 100s, beginning with the lowest number at the far left of the top line. Using the table, locate the correct place on the line for each State.

2. Write the abbreviation for the State and the amount of stored spent fuel given in the table. If more than one State belongs in a given place, "stack" the abbreviations.

   For example, for Virginia and New Jersey:

   NJ - 1,080
   VA - 1,088
   1,000 ——————————— 1,100

3. Looking ahead to the map legend, see where the volumes are broken up into categories. The first category of States with inventories of spent fuel, for example, spans from one to 300 metric tons.

4. Draw an arrow on the number line under the numbers where spent fuel volumes are divided into categories to be colored for the map.

Map: Look at the number line for the groups of States with spent fuel inventories. Remember that each arrow represents a division from the legend.

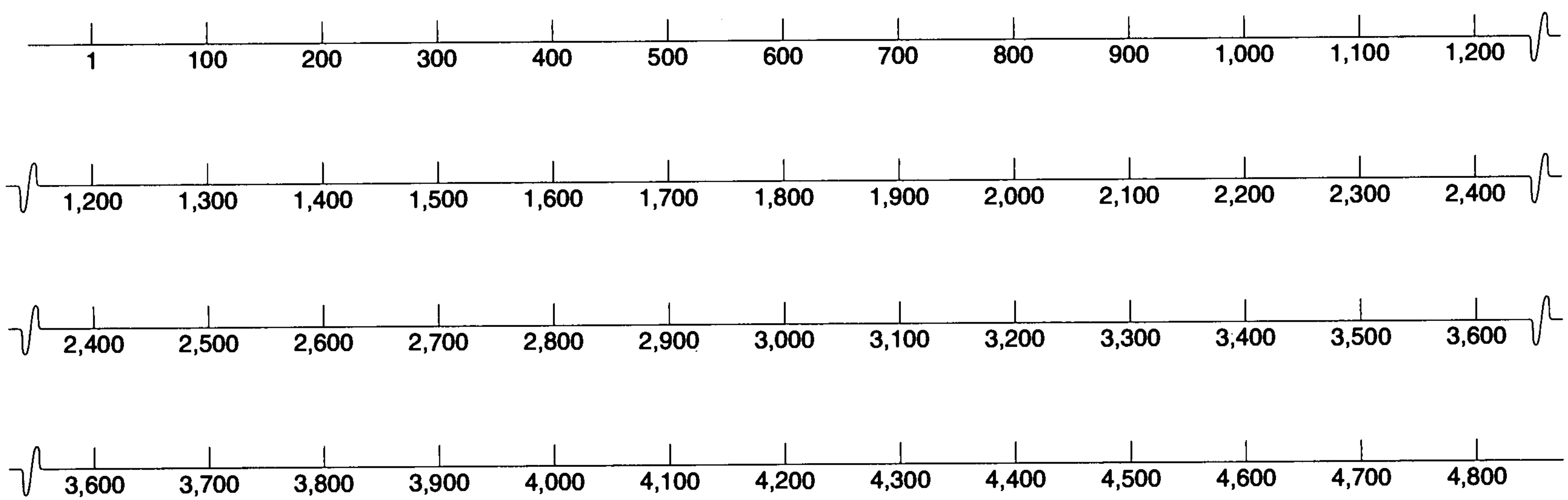
5. Select symbols or colors for the categories. Plan to leave States with no spent fuel blank. Use lighter symbols or colors for States with lower inventories of spent fuel and darker symbols or colors for States with greater inventories.

6. Fill in the map legend. Be sure to leave the box for States with no spent fuel blank.

7. Fill in the map with the colors or symbols you chose to show inventories of spent fuel in the United States.

8. Look at the filled-in map carefully. What patterns do you see? Where is the most or the least spent fuel located? What are some of the possible reasons for these patterns?

SPENT FUEL INVENTORIES NUMBER LINE



Symbol indicates that the number line is a segment of the range in values.

SPENT NUCLEAR FUEL

State	Spent Fuel 1993 (Metric Tons)	State	Spent Fuel 1993 (Metric Tons)	State	Spent Fuel 1993 (Metric Tons)	State	Spent Fuel 1993 (Metric Tons)
Alabama	1,334	Illinois	4,154	Mississippi	299	Pennsylvania	2,284
Arizona	430	Iowa	231	Missouri	242	South Carolina	1,684
Arkansas	554	Kansas	194	Nebraska	350	Tennessee	409
California	1,253	Louisiana	318	New Hampshire	63	Texas	320
Colorado	15	Maine	426	New Jersey	1,080	Vermont	365
Connecticut	1,189	Maryland	578	New York	1,792	Virginia	1,088
Florida	1,320	Massachusetts	431	North Carolina	1,460	Washington	191
Georgia	915	Michigan	1,149	Ohio	395	Wisconsin	779
Idaho	51	Minnesota	610	Oregon	358		

1993 INVENTORIES OF SPENT FUEL BY STATE
(In Metric Tons)

176 177

WORLDWIDE NUCLEAR WASTE MANAGEMENT

Fill in the matrix below while watching the videotape *Worldwide Nuclear Waste Management.* The matrix will give you the data needed to complete the discussion questions.

Country	Number of Powerplants	Number of Sites	Percent of Electricity Derived from Nuclear Power	Reprocess (Yes/No/NA*)	Year Repository is to Open or Be Sited
Belgium					
Canada					
Finland					
France					
Germany					
Japan					
The Netherlands					
Spain					
Sweden					
Switzerland					
United Kingdom					
United States					

*NA = Information not available

NOTE: Since 1992, nuclear waste management programs have also been considered in Argentina, India, and Italy.

Discussion Questions

1. What is the total number of nuclear powerplants for the 11 countries other than the U.S.?

   ____

2. Which country receives the highest percentage of electricity from nuclear power? ______________

   The lowest percentage? ____

3. What is the average percentage of electricity from nuclear power for these 12 countries?

   ____

4. Which country has the most nuclear powerplants? __________ The least? ______________

5. Does the country with the most nuclear powerplants also have the highest percentage of nuclear power? ____

6. If not, why would a country with fewer nuclear powerplants have a higher percentage of electricity derived from nuclear power? Explain.

   ____

   ____

   ____

   ____

7. How many countries reprocess their fuel? ______________________________

8. What is the common goal for these and all other countries who operate nuclear powerplants?

   ____

   ____

9. In what kind of facility do these countries plan to store high-level nuclear waste?

   ____

10. When should siting or operation of these storage facilities begin for most of these countries?

    ____

LOW-LEVEL WASTE

Low-level nuclear waste and high-level nuclear waste have different characteristics and, therefore, are disposed of differently. Historically, some quantity of low-level radioactive waste has been generated in every State from a variety of commercial sources, including academic, government, and industrial research; manufacturing processes; medical diagnosis and therapy; and electricity generation. Currently, these wastes are disposed of at Federally licensed sites in Barnwell, South Carolina and Hanford, Washington. A third site, Beatty, Nevada, closed at the end of 1992, but still contains waste.

To provide a national disposal system to manage low-level wastes, the U.S. Congress passed the Low-Level Radioactive Waste Policy Act and amendments. These laws make disposal of commercially generated low-level radioactive waste a responsibility of each State. States are encouraged to form interstate compacts to manage and dispose of low-level waste on a regional basis. The District of Columbia and Puerto Rico must also comply with provisions of this law. Nine compact regions have been formed and ratified by Congress: Texas, Maine, and Vermont have agreed at the State level to form a tenth compact with Texas as the host State. This agreement has not been approved by Congress at this date. New York and Massachusetts have declared themselves independent host States. As of March 1994, three States, as well as Washington, D.C. and Puerto Rico, remain unaffiliated. Unaffiliated States and States in compacts without an operating disposal site are required to meet specific milestones and deadlines leading to the operation of new regional disposal facilities by January 1, 1993. However, as of 1994, these milestones had not been met by the affected States.

1993 Sources and Volumes of Low-Level Waste Received at Disposal Sites (Cubic Feet)

	Academic	Government	Industry	Medicine	Utilities	Total
APPALACHIAN COMPACT	**1,503**	**6,326**	**3,760**	**117**	**48,811**	**60,517**
Delaware	4	1	489	7	0	501
Maryland	1,256	5,984	770	9	3,346	11,365
Pennsylvania	228	341	2,489	101	45,465	48,624
West Virginia	15	0	12	0	0	27
CENTRAL COMPACT	**647**	**251**	**205**	**39**	**23,598**	**24,740**
Arkansas	16	81	0	19	2,774	2,890
Kansas	118	4	160	16	2,428	2,726
Louisiana	331	1	30	1	6,798	7,161
Nebraska	165	5	0	0	11,598	11,768
Oklahoma	17	160	15	3	0	195
CENTRAL MIDWEST COMPACT	**420**	**22**	**2,891**	**214**	**63,436**	**66,983**
Illinois	218	2	2,645	214	63,436	66,515
Kentucky	202	20	246	0	0	468
MIDWEST COMPACT	**2,435**	**49**	**4,207**	**52**	**13,380**	**20,123**
Indiana	272	11	684	0	0	967
Iowa	525	0	8	0	1,474	2,007
Minnesota	655	2	282	0	4,118	5,057
Missouri	534	0	1,041	4	1,610	3,189
Ohio	400	31	2,175	48	4,023	6,677
Wisconsin	49	5	17	0	2,155	2,226

Table Continued

	Academic	Government	Industry	Medicine	Utilities	Total
NORTHEAST COMPACT	**1,212**	**983**	**5,331**	**86**	**28,066**	**35,678**
Connnecticut	642	872	1,667	18	11,403	14,602
New Jersey	570	111	3,664	68	16,663	21,076
NORTHWEST COMPACT	**1,469**	**114,909**	**16,018**	**237**	**15,445**	**148,078**
Alaska	0	447	0	0	0	447
Hawaii	0	2,361	0	0	0	2,361
Idaho	300	23	2	0	0	325
Montana	0	0	0	0	0	0
Oregon	326	95,857	3,631	9	4	99,827
Utah	0	0	6,524	0	0	6,524
Washington §	843	16,221	5,861	228	15,441	38,594
Wyoming	0	0	0	0	0	0
ROCKY MOUNTAIN COMPACT	**326**	**0**	**12**	**0**	**38,333**	**38,671**
Colorado	326	0	0	0	38,333	38,659
Nevada	0	0	0	0	0	0
New Mexico	0	0	12	0	0	12
SOUTHEAST COMPACT	**2,727**	**51,699**	**120,851**	**1,340**	**99,275**	**275,892**
Alabama	10	214	187	21	12,645	13,077
Florida	184	143	813	74	11,312	12,526
Georgia	313	63	1,271	79	11,506	13,232
Mississippi	31	71	554	13	6,703	7,372
North Carolina	1,522	38	15,061	1,099	19,309	37,029
South Carolina §	243	8,513	8,315	5	18,401	35,477
Tennessee	320	6	82,364	44	1,924	84,658
Virginia	104	42,651	12,286	5	17,475	72,521
SOUTHWEST COMPACT	**115**	**10,511**	**3,560**	**419**	**13,366**	**27,971**
Arizona	0	5	0	0	8,148	8,153
California	115	10,493	3,560	419	5,218	19,805
North Dakota	0	4	0	0	0	4
South Dakota	0	9	0	0	0	9
UNAFFILIATED (Not members of any compact as of 1992)	**1,318**	**6,599**	**27,925**	**2,632**	**55,055**	**93,529**
Army Outside of U.S.	0	2,506	0	0	0	2,506
District of Columbia	0	0	0	0	0	0
Maine*	0	0	0	0	0	0
Massachusetts	200	3,384	4,819	131	16,431	24,965
Michigan	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0
New York	633	386	19,787	2,472	28,346	51,624
Puerto Rico	0	0	0	0	0	0
Rhode Island	0	0	0	0	0	0
Texas*	464	322	3,319	29	5,667	9,801
Vermont*	21	1	0	0	4,611	4,633
TOTAL	**12,172**	**191,349**	**184,760**	**5,136**	**398,765**	**792,182**

Note: Due to computer-generated rounding, totals may not add up exactly.

§ *Current location of disposal site. (Washington will host a site for the Northwest Compact and the Rocky Mountain Compact.)*

* *As of March 1994, Texas, Maine, and Vermont had agreed to form a tenth compact.*

Source: The 1993 State-by-State Assessment of Low-Level Radioactive Wastes Received at Commercial Disposal Sites *(DOE/LLW-205), September 1994.*

LOW-LEVEL WASTE

Part I

A thematic map provides information about a single topic. Thematic maps with shaded or colored areas are choropleth maps. Their shadings enable readers to see patterns quickly, and for this reason, shading is usually progressively darker as data values increase.

Directions: Make two thematic maps, called choropleth maps, to show 1) what States have joined which low-level waste compacts and 2) how much low-level waste from individual States was disposed of at federally licensed sites in 1993.

Use data from the table given, *Low-Level Waste Received at Disposal Sites – 1993* to fill in the data table and worksheet. This information will be used later to complete the maps.

1. Identify the range of numbers of low-level waste disposed of in the United States by recording the lowest and highest numbers.
   ____________ to ______________________________.

2. Because the range is so wide, it will be necessary to convert to units that can be managed more easily. Using the data table on the activity entitled *Low-Level Waste Number Line*, convert the data to units of thousands of cubic feet.

   a) Round the numbers to the nearest 1,000.
   (For example, 501 = 1,000; 11,365 = 11,000; 27 = 0)
   Record these numbers on the first blank for each State. In the second blank, record the data in units of thousands.

   For example:
   For Delaware: DE *1,000 1*

   For Maryland: MD *11,000 11*

3. Complete the number line on the worksheet. Each division on the number line represents 10,000 cubic feet of low-level waste.

   a. Locate the correct place on the line for each State.

   b. Write the abbreviation for the State and the amount of low-level waste as calculated in Step 2. If more than one State belongs in a given place, "stack" the abbreviations.

   For example, for DE and AR:

   DE - 1
   AR - 3
   0 10

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4. List the low-level waste compacts and assign symbols or colors for each compact in the legend on the worksheet. Place States that have not joined a compact into a group such as "Unaffiliated States."

5. Using the information from Step 4, fill in the legend for the map titled "Low-Level Waste Compacts, – December 1993."

6. Fill in the map to identify what States have joined which low-level waste compacts.

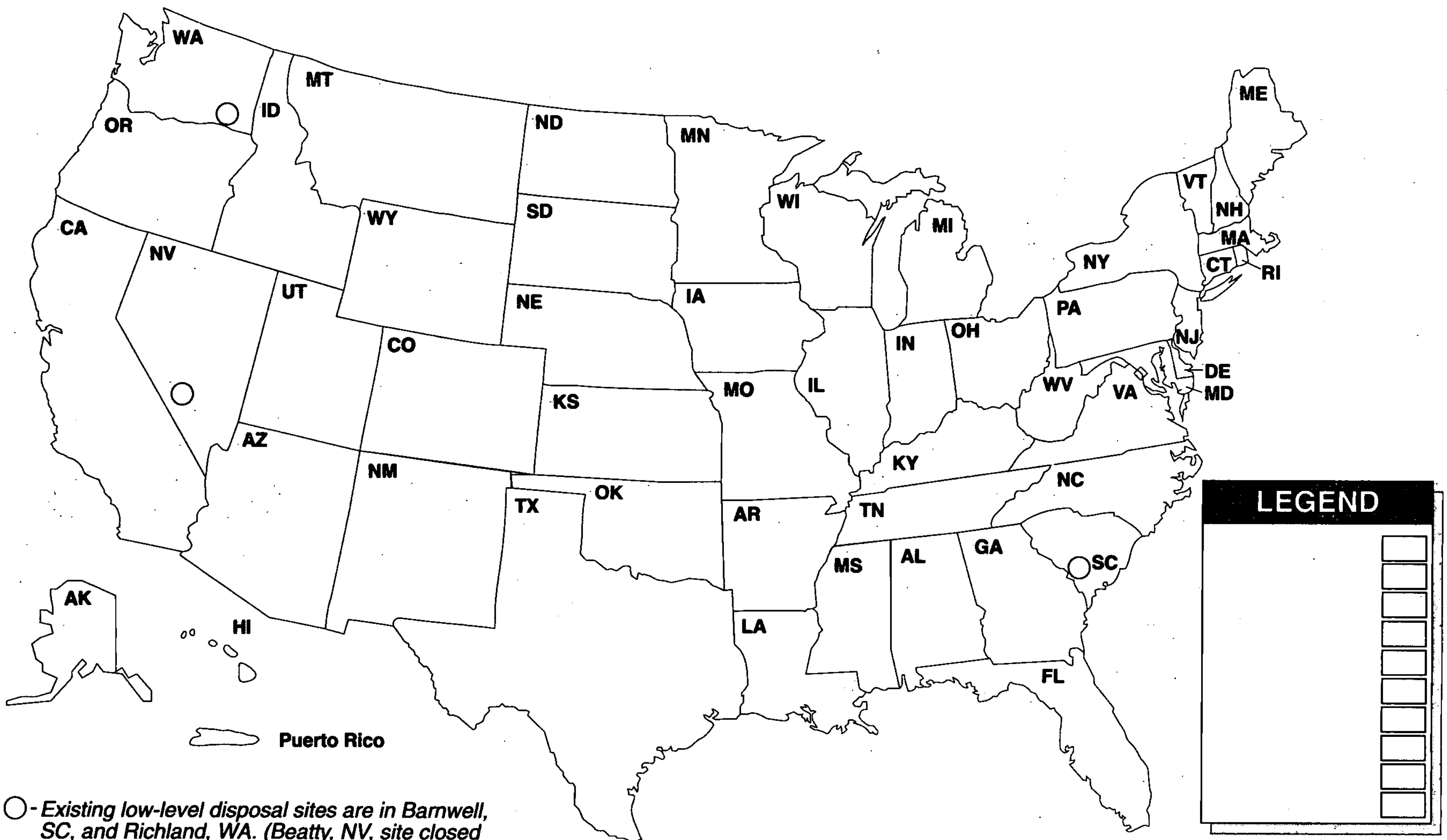
7. Next, establish four or five categories for the amount of waste received at disposal sites and fill in the second column of the legend on the worksheet. The categories do not have to represent equal breakdowns by numbers on the number line or by number of States.

   In determining the categories, look for major clusters in distribution along the number line. Distinguish groups that are basically alike or clearly different.

8. Select symbols or colors for the categories you created in Step 7. Fill in the legend for the map titled "Low-Level Waste Received at Disposal Sites – 1993."

9. Fill in the map "Low-Level Waste Compacts, December 1993" to depict the amount of low-level waste each state has sent to disposal sites.

LOW-LEVEL WASTE COMPACTS, DECEMBER 1993



○ - Existing low-level disposal sites are in Barnwell, SC, and Richland, WA. (Beatty, NV, site closed December 31, 1992.)

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Low-Level Waste Number Line

DE ________ ____	CT ________ ____	NC ________ ____
MD ________ ____	NJ ________ ____	SC ________ ____
PA ________ ____	AK ________ ____	TN ________ ____
WV ________ ____	HI ________ ____	VA ________ ____
AR ________ ____	ID ________ ____	AZ ________ ____
KS ________ ____	MT ________ ____	CA ________ ____
LA ________ ____	OR ________ ____	ND ________ ____
NE ________ ____	UT ________ ____	SD ________ ____
OK ________ ____	WA ________ ____	DC ________ ____
IL ________ ____	WY ________ ____	ME ________ ____
KY ________ ____	CO ________ ____	MA ________ ____
IN ________ ____	NV ________ ____	MI ________ ____
IA ________ ____	NM ________ ____	NH ________ ____
MN ________ ____	AL ________ ____	NY ________ ____
MO ________ ____	FL ________ ____	PR ________ ____
OH ________ ____	GA ________ ____	RI ________ ____
WI ________ ____	MS ________ ____	TX ________ ____
		VT ________ ____

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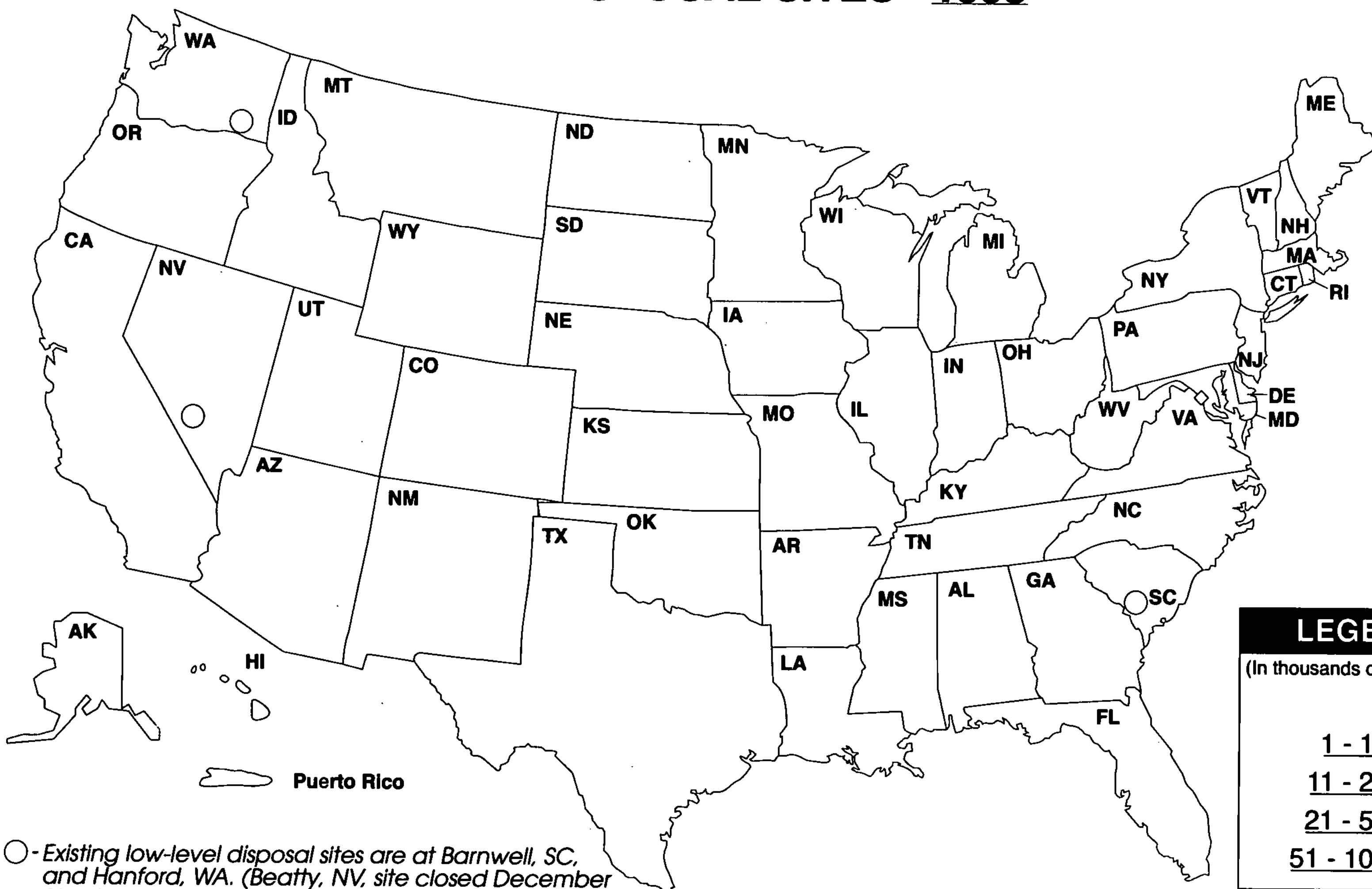
LOW-LEVEL WASTE RECEIVED AT DISPOSAL SITES - 1993



LEGEND

(In thousands of cubic feet)

0	☐
1 - 10	☐
11 - 20	☐
21 - 50	☐
51 - 100	☐

○ - *Existing low-level disposal sites are at Barnwell, SC, and Hanford, WA. (Beatty, NV, site closed December 31, 1992.)*

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LOW-LEVEL WASTE

Part II

Directions: Study and complete the table and pie chart below for low-level waste volumes disposed of in the U.S. as of 1993. Then construct a pie chart (circle graph) for low-level waste disposed of in your state and compare the two charts.

Percentages of low-level waste disposal in the United States.

1. Complete the U.S. volume-to-degree conversions as practice before calculating percentages for your own state. For example, to get the academic source percentage of low-level waste for the pie chart below:

   12,172 ÷ 792,182 = 0.0154 (source/total)

   Convert to percent = 1.5% (rounded to nearest half-percent)

   Convert to degrees = 1.5% x 360° ÷ 100% = 5.5°

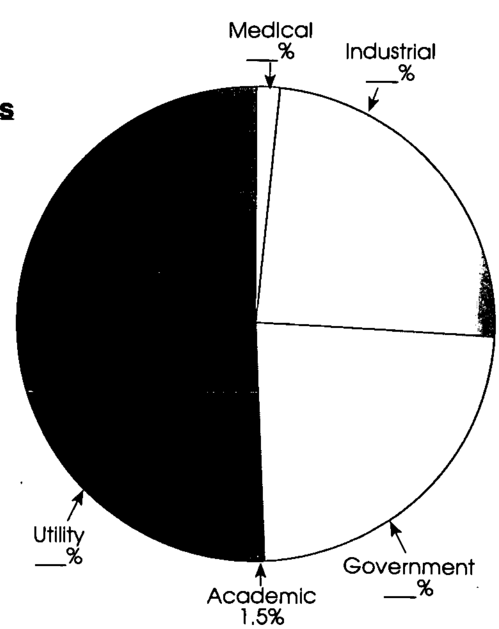
   (See the electricity production enrichment activity Making a Pie Chart - United States, *or ask your teacher for help in converting volumes to percents and degrees)*

2. Fill in the missing percentages and degrees for the pie chart below.

Low-Level Waste Disposed of in the United States:

Source	Volume (Cubic Feet)	Decimal Fraction	Percent	Degrees
Academic	12,172	*0.0154*	*1.5%*	*5.4°*
Government	191,349	*0.2415*	____	____
Industrial	184,760	*0.2332*	____	____
Medical	5,136	*0.0065*	____	____
Utility	398,765	*0.5034*	____	____
Total	**792,182**		**100%**	**360°**

VOLUME PERCENTAGE BY SOURCE



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Percentages of low-level waste disposal in your State.

Using the data given in the table entitled *1993 Volumes of Low-Level Waste Received at Disposal Sites*, make a pie chart to show the percentage of low-level waste disposed of by your home State in 1993 that came from each of the following sources: academic, government, industrial, medical, electrical utilities. (If your home State did not dispose of low-level waste at one of the disposal sites in 1993, or if all the waste disposed of came from a single source, use the data for the compact your State belongs to or a neighboring State.)

1. Identify below the State for which calculations are being made and write in the volumes from the table entitled *1993 Volumes of Low-Level Waste Received at Disposal Sites.*

2. Calculate the fraction, expressed as a decimal, of the total for each source.

3. Round off and convert the decimal to percent.

4. Figure the number of degrees of a circle that will represent each percentage. (Remember that a circle has 360°. This means 50% will equal 180°, 25% will equal 90°, 10% will equal 36°, etc.)

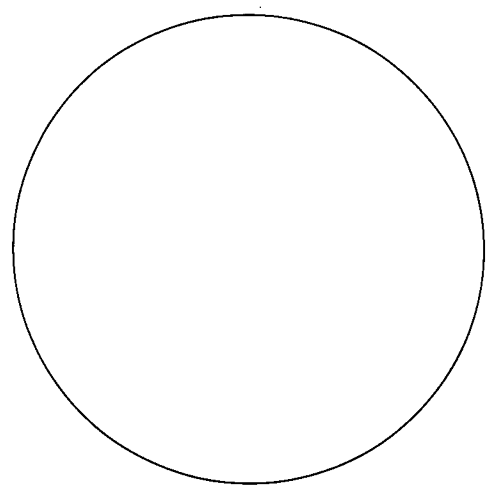
5. Using a protractor, use the circle below to make your pie chart.

6. Label the pie chart with the percentages and the categories they represent.

Low-Level Waste Disposed of in ______________________:

Source	Volume (Cubic Feet)	Decimal Fraction	Percent	Degrees
Academic	________	______	______	______
Government	________	______	______	______
Industrial	________	______	______	______
Medical	________	______	______	______
Utility	________	______	______	______
Total	________			

VOLUME PERCENTAGE BY SOURCE



(Answers will vary)

METRIC AND U.S. UNIT CONVERSIONS

Both American and metric units have been used in the curriculum, as appropriate to the issues being discussed. For example, inventories of spent fuel are routinely reported in the United States in terms of metric tons (1,000 kilograms) even though most Americans are familiar with the short ton (2,000 pounds). Classroom experiments are usually conducted using metric units as well. Yet the standards and tests for spent fuel transportation casks are written using temperature in degrees Fahrenheit, miles per hour, and other similar units.

To familiarize yourself with potentially unfamiliar metric units, a conversion chart has been prepared. To convert a given unit into its metric or U.S. equivalent, multiply the quantity by the number in the right hand column. For example, to convert 1,000 kilograms into its equivalent in pounds, multiply by 2.205 to get 2,205 pounds (1,000 kg x 2,205 lb/kg = 2,205 lb). Alternately, 2,000 pounds is equivalent to 2,000 lb x 0.4536 kg/lb or 907.2 kilograms.

People vary in their comprehension of metric units and unfamiliar U.S. units. Consider using this chart as an aid if you are confused or if you are especially interested in unit conversions.

Table 1. Approximate Conversions from Metric to English Units

If you know...

Length →	**multiply by** →	**to get**
millimeters (mm)	0.03937	inches (in)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.3937	inches (in)
meters (m)	39.37	inches (in)
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
kilometers (km)	3,281.0	feet (ft)
kilometers (km)	0.5396	nautical miles (mi)
kilometers (km)	0.6214	statute miles (mi)
Area		
hectares (ha)	2.471	acres
hectares (ha)	1.076 X 105	square ft (ft^2)
Weight (mass)		
grams (gm)	0.03527	ounces (oz)
grams (gm)	0.002205	pounds (lb)
kilograms (kg)	2.205	pounds (lb)
metric tons (t)	1.102	short tons
metric tons (t)	0.984	long tons
Pressure		
kilopascals (kPa)	6.9	pounds/square inch (lb/in^2)
Volume		
cubic centimeters (cm^3)	0.06202	cubic inches (in^3)
cubic meters (m^3)	3.531	cubic feet (ft^3)
cubic meters (m^3)	1.307	cubic yards (yd^3)
liters (L)	2.113	pints* (pt)
liters(L)	0.2642	gallons* (gal)
Temperature		
Celsius	9/5, [then add 32]	Fahrenheit
Electric Current		
ampere (A)	1	ampere (A)
Energy, Work, Heat		
joule (J)	9.480×10^{-4}	BTU
Power		
watt (W)	1	watt (W)
watt (W)	3.4129	BTU per hour
watt (W)	1.341×10^{-3}	horsepower

Common Prefixes for Metric Units:

mega = million = 10^6	deci = one-tenth
kilo = thousand	centi = one-hundredth
hecto = hundred	milli = one-thousandth
deka = ten	micro = one-millionth
Examples:	kilogram = 1,000 grams
	milliliter = 1/1,000 liter

*liquid measure

Table 2. Approximate Conversions from English to Metric Units

If you know...

Length →	multiply by →	to get
inches (in)	2.54	centimeters (cm)
feet (ft)	30.48	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
yards (yd)	0.9144	meters (m)
Area		
square inches (in^2)	6.5	square centimeters (cm^2)
square feet (ft^2)	0.09	square meters (m^2)
square yards (yd^2)	0.8	square meters (m^2)
acres	0.4047	hectares (ha)
square miles (mi^2)	2.6	square kilometers (k^2)
Weight (mass)		
ounces (oz)	28.349527	grams (gm)
pounds (lb)	0.4536	kilograms (kg)
tons (long)	1.016	metric ton (t)
Pressure		
pounds per square inch	70.31	grams per square centimeter
pounds per square inch	0.145	kilopascals
Volume		
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic inches (in^3)	16.387	cubic centimeters (cm^3)
cubic yards (yd^3)	0.765	cubic meters (m^3)
gallons* (gal)	3.785	liters (L)
pints* (pt)	0.473	liters (L)
quarts* (qt)	0.946	liters (L)
Temperature		
Fahrenheit	[subtract 32, then multiply by 5/9]	Celsius
Electric Current		
ampere (A)	1	ampere (A)
Energy, Work, Heat		
BTU	1,055	joules (J)
Power		
watt (W)	1	watt (W)
BTU per hour	0.293	watt (W)
horsepower	745.712	watt (W)

*liquid measure

TEST

MANAGING OUR NATION'S NUCLEAR WASTE
PRETEST

Directions: Circle the letter of the answer that **BEST** completes the statement.

1. Most of our Nation's electricity comes from:

   a. hydropower, coal, and nuclear energy

   b. coal and nuclear energy

   c. nuclear energy and hydropower

   d. oil and coal

2. The four categories of nuclear waste are:

   a. transuranic, low-level, high-level, and bottom ash

   b. transuranic, low-level, high-level, and mill tailings

   c. bottom ash, low-level, high-level, and mill tailings

   d. low-level, high-level, bottom ash, and mill tailings

3. Of the following, the largest total volume (space occupied) is occupied by:

   a. low-level waste

   b. high-level waste

   c. spent fuel

   d. transuranic waste

4. Permanent disposal of <u>high-level</u> nuclear waste is the responsibility of:

   a. the States where the waste is produced

   b. the electric utilities that produce the waste

   c. the Federal Government

   d. local governments where the waste is produced

5. Radioactivity is:

   a. the emission of heat from a chemical reaction

   b. spontaneous combustion of a material

   c. spontaneous emission of particles and rays by an atom

   d. the emission of light from a chemical reaction

6. The <u>most penetrating</u> type of ionizing radiation emitted by nuclear waste is the:

   a. alpha particle

   b. beta particle

   c. proton

   d. gamma ray

7. Because it deposits more energy per unit path length, the type of radiation most likely to cause biological damage is the:

   a. alpha particle

   b. beta particle

   c. proton

   d. gamma ray

8. In the United States, the source of greatest exposure to radiation for the average person is:

   a. nuclear powerplants and nuclear waste

   b. facilities where nuclear weapons are produced

   c. medical diagnosis and treatment

   d. cosmic rays, rocks, and soil in our natural environment

9. We receive an internal exposure to radiation from the presence of radioactive ____ in our bodies and some essential foods:

   a. oxygen

   b. potassium

   c. hydrogen

   d. iron

10. Radioactive materials become less radioactive over time through the process of:

    a. spontaneous combustion

    b. atomization

    c. chemical reaction

    d. radioactive decay

11. The amount of radiation the average American is exposed to annually from all sources is:

    a. 125 millirem

    b. 360 millirem

    c. 420 millirem

    d. 540 millirem

12. In the Nuclear Waste Policy Act, Congress gave responsibility for the development of a system for safe disposal of high-level nuclear waste to:

    a. the President of the United States

    b. the U.S. Environmental Protection Agency (EPA)

    c. the U.S. Nuclear Regulatory Commission (NRC)

    d. the U.S. Department of Energy (DOE)

13. The Low-Level Radioactive Waste Policy Act is designed to:

    a. make waste less radioactive

    b. require each State to provide for safe disposal of low-level wastes either within the State or a regional compact

    c. encourage States to try new disposal technologies

    d. fund new disposal sites

14. The purpose of site characterization is:

    a. to gather data that can be used to design the repository itself

    b. to gather data that can be used to design the waste container

    c. to gather data needed to determine whether the site is suitable for a repository

    d. all of the above

15. An advantage for a potential repository site would be:

    a. high annual rainfall

    b. nearness to a large city

    c. a repository location in the unsaturated zone

    d. complete absence of zeolites in the rock

16. All countries planning permanent disposal of spent fuel plan some kind of:

    a. geologic disposal deep underground

    b. ocean disposal

    c. above ground repository disposal

    d. spent fuel pool disposal

17. One type of waste that will be disposed of in a deep geologic repository is:

    a. low-level nuclear waste

    b. medical waste

    c. mill tailings

    d. spent fuel

18. The costs of disposing of spent fuel from nuclear powerplants will be paid by:

    a. fees charged to utilities that use nuclear energy to produce electricity

    b. Federal income taxes in States that have nuclear powerplants

    c. State taxes in States that have nuclear powerplants

    d. Federal taxes in States where waste is produced, stored, or disposed of

19. Spent fuel from nuclear powerplants is currently stored in:

    a. 15 States

    b. 28 States

    c. 34 States

    d. 48 States

20. A State being considered for a repository may enter into a Benefits Agreement that entitles the State to:

    a. receive $10 million annually before the repository opens and $20 million annually after it opens

    b. veto any site in the State and prevent its use as a repository forever

    c. name an alternate site in the State for a repository

    d. build and operate a repository itself for profit

21. All transportation of high-level nuclear waste to a repository must be in shipping casks:

    a. certified by the Nuclear Regulatory Commission

    b. tested by the U.S. Department of Transportation

    c. developed by the U.S. Department of Energy

    d. regulated by the Environmental Protection Agency

22. The disposal system will be designed to isolate spent fuel from the environment until the waste is no more dangerous than:

    a. low-level waste

    b. the ore the nuclear fuel came from

    c. solid waste in a municipal landfill

    d. none of the above

23. Waste placed in the repository will be in special:

    a. liquid and glass forms

    b. solid and liquid forms

    c. solid forms

    d. gaseous, solid, and liquid forms

24. The multiple barrier system in the repository is:

    a. a man-made and natural barrier system

    b. the host rock

    c. the solid form of the waste and its container

    d. all of the above

25. One societal challenge of the waste management program is:

    a. the waste will continue to generate heat for many years

    b. the disposal facility must be built to keep the waste isolated from the environment for many years

    c. one State or Indian Tribe will be asked to bear the burden of hosting a waste facility for waste from many States

    d. the waste container must keep the waste isolated from environment for many years

1. B	11. B	21. A
2. B	12. D	22. B
3. A	13. B	23. C
4. C	14. D	24. D
5. C	15. C	25. C
6. D	16. A	
7. A	17. D	
8. D	18. A	
9. B	19. C	
10. D	20. A	

MANAGING OUR NATION'S NUCLEAR WASTE

POSTTEST

Directions: Circle the letter of the answer that **BEST** completes the statement.

1. Nuclear energy supplies slightly more than ____ of our Nation's electricity:

   a. 5%

   b. 10%

   c. 20%

   d. 40%

2. Which of the following is **NOT** a category of nuclear waste?

   a. bottom ash

   b. high-level waste

   c. low-level waste

   d. transuranic waste

3. Most of the radioactivity in nuclear waste is found in:

   a. low-level waste from nuclear powerplants

   b. low-level waste from defense activities

   c. spent fuel from nuclear powerplants

   d. transuranic waste from defense activities

4. In 1993, final disposal of low-level nuclear waste from nuclear powerplants became the responsibility of the:

   a. electric utilities that produce the waste

   b. States where the waste is produced

   c. Federal Government

   d. local governments where the waste is produced

5. The spontaneous emission of ionizing radiation in the form of particles and rays by an atom is called:

   a. radioactivity

   b. atomization

   c. spontaneous combustion

   d. current emissions

6. The least penetrating type of ionizing radiation emitted by nuclear waste is the:

   a. alpha particle

   b. beta particle

   c. proton

   d. gamma ray

7. Because it deposits less energy per unit path length, the type of radiation least likely to cause biological damage is the:

   a. alpha particle

   b. beta particle

   c. proton

   d. gamma ray

8. In the United States, the source of the <u>least</u> annual radiation exposure for the average person is:

   a. nuclear powerplants and waste from the nuclear fuel cycle

   b. medical diagnosis and treatment

   c. cosmic rays, rocks, and soil in our natural environment

   d. radon

9. Some of our internal exposure to radiation comes from the presence of radioactive ______ in our bodies and some essential foods:

   a. iron

   b. oxygen

   c. carbon

   d. hydrogen

10. Over time, as a result of radioactive decay, nuclear waste will:

    a. significantly decrease in mass and volume (space occupied)

    b. retain the same level of radioactivity but cool down

    c. become less radioactive

    d. become more radioactive

11. The average American receives an annual exposure to radiation of about 360 millirem from:

    a. nuclear powerplants

    b. cosmic radiation

    c. medical diagnosis

    d. all sources

12. The 1987 decision to study only Yucca Mountain, Nevada, to see if it will be suitable for disposal of high-level waste was made by:

    a. the State of Nevada

    b. the U.S. Congress

    c. the U.S. Environmental Protection Agency (EPA)

    d. the U.S. Department of Energy (DOE)

13. According to the Low-Level Radioactive Waste Policy Act, low-level wastes may be:

    a. stored by the State or a region compact facility

    b. stored indefinately in Hanford, Washington, and Barnwell, South Carolina

    c. must be stored in a geologic repository

    d. cannot be disposed of

14. During site characterization, some studies will focus on:

    a. the geology of the site

    b. the hydrology of the site

    c. potential for earthquakes or volcanic activity

    d. all of the above

15. A disadvantage for a potential repository site would be:

    a. a repository location in the unsaturated zone

    b. the presence of zeolites in the rock

    c. land owned by the Federal government

    d. potential for seismic (earthquake) activity

16. Geologic disposal of high-level nuclear waste in a repository is being planned:

    a. only by the United States

    b. only by the United States, France, and the United Kingdom

    c. by all countries with high-level nuclear waste, except the United States

    d. by all countries with high-level nuclear waste, including the United States

17. High-level nuclear waste from defense activities and spent fuel from nuclear powerplants will be permanently disposed of:

    a. in a mined geologic repository deep underground

    b. in above-ground specially designed concrete repositories

    c. in spent fuel pools

    d. in sub-seabed geologic repositories

18. The costs of disposing of high-level waste from defense activities will be paid by:

    a. fees charged to utilities that use nuclear energy to produce electricity

    b. State income taxes in all 50 States

    c. special fees in States that have military bases

    d. the Federal Government

19. By the year 2000, it is expected that cumulative inventories of spent fuel from nuclear powerplants will:

    a. stay the same

    b. nearly double

    c. triple

    d. decrease

20. If the President recommends a site for a repository to the U.S. Congress, the State where the site is located may:

    a. impose user fees

    b. veto the site and prevent its use unless Congress overrides the veto

    c. name an alternate site in the State for a repository

    d. all of the above

21. To receive certification by the Nuclear Regulatory Commission, a cask must pass a:

    a. drop test

    b. fire test

    c. water immersion test

    d. all of the above

22. Spent fuel must be isolated from the environment until the total hazard it presents reaches the hazard of uranium ore, in about:

    a. one hundred years (100)

    b. ten thousand years (10,000)

    c. one million years (1,000,000)

    d. ten million years (10,000,000)

23. Waste placed in the repository **CANNOT** be in:

    a. ceramic form

    b. glass form

    c. liquid form

    d. solid form

24. The repository will isolate the waste from the environment by:

    a. the host rock alone

    b. a multiple barrier system

    c. the solid form of the waste alone

    d. the waste container alone

25. One technical challenge of the waste management program is:

    a. one State will be asked to bear the burden of hosting a waste facility for waste from many States

    b. the waste facility must be designed to withstand the heat that the waste will continue to produce for many years

    c. waste shipments will travel through many States on the way to the disposal facility, whether or not it was produced in those States

    d. States may disagree about which State should host the regional compact disposal facility

1. C	11. D	21. D
2. A	12. B	22. B
3. C	13. A	23. C
4. B	14. D	24. B
5. A	15. D	25. B
6. A	16. D	
7. D	17. A	
8. A	18. D	
9. C	19. B	
10. C	20. B	

NAME ______________________________

Directions: Circle the letter of the answer that best completes the statement given.

1. Energy released during fission is called nuclear energy because of the fissioning of the ____________.

   a. proton
   b. neutron
   c. electron
   d. nucleus

2. Many universities and hospitals produce radioactive wastes that contain a small amount of radioactivity dispersed throughout a large amount of material. These wastes are considered to be:

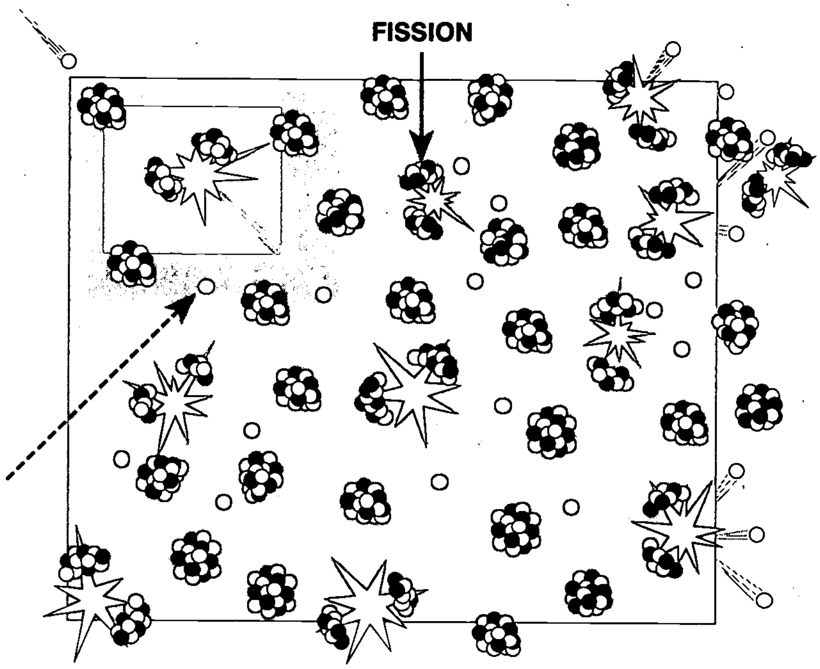
   a. low-level waste
   b. high-level waste
   c. transuranic waste
   d. mill tailings

3. Transuranic waste requires special disposal not because it is highly radioactive but because it:

   a. is composed of rocks and soils from mining and milling uranium ore
   b. contains materials that will quickly undergo radioactive decay
   c. contains materials that will require very long periods of time to undergo radioactive decay

4. Spent fuel and waste from defense activities that are usually highly radioactive and must be handled remotely are considered to be:

   a. low-level waste
   b. high-level waste
   c. transuranic waste
   d. mill tailings



5. In the United States, most fuel is currently stored in:

   a. a deep underground repository
   b. concrete casks at the reactor site
   c. deep pools of water at the reactor site
   d. shallow land burial sites

Use the diagram of the fission process above to answer questions 6 and 7.

6. The dashed arrow points to a ______, which begins the fission process. When present in significant numbers these keep the fission reaction going.

   a. transuranic
   b. uranium atom
   c. neutron
   d. fission product

7. The solid arrow points to a ___________, which is produced during the fission process.

   a. transuranic
   b. uranium atom
   c. neutron
   d. fission product

8. By volume most nuclear waste is:

   a. high-level waste
   b. low-level waste
   c. transuranic waste
   d. uranium mill tailings

9. High-level waste includes:

   a. waste from industrial processes
   b. byproducts from nuclear medicine activities
   c. rocks and soil from mining and milling uranium
   d. spent fuel from nuclear powerplants

10. The percentage of electricity generated in the United States by nuclear powerplants is slightly more than:

   a. 50%
   b. 30%
   c. 20%
   d. 10%

11. According to the Low-Level Radioactive Waste Act of 1980, a compact is:

   a. an agreement between the United States and State governments
   b. a law regarding the disposal of high-level nuclear waste
   c. an organization of States that will dispose of the low-level waste of its members
   d. an organization of States that will dispose of the high-level waste of its members

12. Nuclear waste requires special disposal because it:

   a. is fluorescent
   b. is radioactive
   c. is a part of nature
   d. is decreasing in quantity

13. The agency responsible for establishing a system for the disposal of high-level radioactive waste is the:

    a. Nuclear Regulatory Commission (NRC)
    b. U.S. Department of Energy (DOE)
    c. Cabinet of the President of the United States
    d. Environmental Protection Agency (EPA)

14. The site that will be studied to see if it is suitable for a geologic repository is:

    a. Hanford, Washington
    b. Barnwell, South Carolina
    c. Oak Ridge, Tennessee
    d. Yucca Mountain, Nevada

15. The process during which neutrons strike the nuclei of uranium-235 atoms, are absorbed and split the nucleus is:

    a. fission
    b. radioactive decay
    c. fusion
    d. reprocessing

16. Transuranic waste will eventually be placed in:

    a. fuel rods
    b. a surface facility
    c. a cooling pond
    d. a geologic repository

17. Under provisions of the amended Low-Level Radioactive Waste Policy Act of 1980, beginning in 1993 each State will ship its low-level nuclear waste to:

    a. Federal facilities in South Carolina or Washington
    b. Yucca Mountain, Nevada
    c. an in-state or regional disposal facility
    d. cooling ponds at local nuclear powerplants

18. In the first 10 years of storage, spent fuel will have lost approximately 90% of its radioactivity due to:

    a. reprocessing
    b. radioactive decay
    c. fission
    d. fusion

19. Low-level waste from nuclear powerplants is currently disposed of at:

    a. a geologic repository
    b. a shallow land burial facility
    c. a spent fuel pool
    d. a cooling pond

20. Mill tailings are disposed of:

    a. at a geologic repository
    b. in casks at a shallow land burial facility
    c. by covering with soil
    d. a cooling pond

1. D	11. C
2. A	12. B
3. C	13. B
4. B	14. D
5. C	15. A
6. C	16. D
7. D	17. C
8. B	18. B
9. D	19. B
10. C	20. C

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